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Population Ecology and Habitat Use of Burrowing Owls in Eastern Washington

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by

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Executive Summary

In 2003, we monitored 121 nesting attempts in Grant and Adams counties and 103 nesting attempts in the Tri-Cities study area. The proportion of monitored burrows that were occupied by owls has been relatively constant over the 3 years at both the central WA study area (45-52%) and the southern WA study area (23-24%). Nesting success was greater in Adams and Grant counties (59%) compared to the Tri-Cities area (40%). The typical nest had 8 eggs, but the number of eggs laid varied from 4 to 11. Clutch size did not differ between the two study areas, but owls in southern WA hatched fewer nestlings and produced fewer fledglings compared to owls in central WA. Successful nests in Adams and Grant counties produced an average of 3.8 fledglings, while successful nests in the Tri-Cities study area produced an average of 2.7 fledglings. However, higher nesting success and higher fecundity in central WA may be a consequence of a supplemental feeding experiment that was part of Victoria Garcia's Masters thesis (to be completed in fall of 2004). Occupancy of artificial burrows in the Tri-Cities area has been very low (<7% of installed burrows). Over the past 4 years, we have banded 1090 burrowing owls in Adams and Grant counties and 942 burrowing owls in the Tri-Cities area. Annual return rate is higher in the Tri-Cities area. The proportion of banded adults that have been re-sighted in a subsequent year is 42% in the Tri-Cities and 31% in Adams/Grant counties. Propensity to use the same nest burrow was higher in Adams/Grant counties. For example, males who returned used the same burrow 59% of the time in Adams/Grant counties but only 39% of the time in the Tri-Cities area. The proportion of banded juveniles that have been re-sighted in a subsequent year is 8% in the Tri-Cities and 4% in Adams/Grant counties. Male owls return at a higher rate than female owls. Owls in southern WA may be helping to sustain populations further north; 5 juveniles from the Tri-Cities study area have shown up as breeders in Adams/Grant counties, but only 1 juvenile from Adams/Grant counties has been re-sighted in the Tri-Cities. Two adults banded in Adams/Grant counties dispersed to the Tri-Cities study area after a failed nesting attempt, but we haven't documented any adults dispersing the other direction. Few of the vegetative and land-use features that we measured reached statistical significance, but several patterns were marginally significant. Successful nest burrows tended to have less cover by native vegetation and less total vegetative cover compared to unsuccessful nest burrows. In Adams/Grant counties, agriculture was the land use encountered at the greatest proportion (65%) of occupied burrows, but burrows near pastures were more likely to be successful and burrows near agriculture and irrigations canals were less likely to be successful. Successful burrows had higher percent of shrub-steppe compared to unsuccessful burrows. In the Tri-Cities area, the land use encountered at the greatest proportion (78%) of occupied burrows was abandoned field, and burrows near roads (paved and gravel) tended to be less successful. In 2003, we radio-collared 83 juveniles from 67 nests: 31 died prior to leaving their natal burrow, 34 left their natal burrow (3 of which later died), we lost the signal on 15 birds (we suspect they dispersed but could not confirm), and 3 had unknown fate. This component of the study is also part of the M.S. thesis by Victoria Garcia. Radio collars did not affect natal recruitment: 5% of juveniles that were radio-collared and 4% of juveniles that were banded but not radio collared have returned as breeders in a subsequent year. Approximately 5% of the adult owls that breed in Adams/Grant counties spend the winter near their nest burrow, whereas approximately 10% of the adult owls that breed in the Tri-Cities area stay the winter. Males are much more likely to over-winter than females, and juveniles rarely stay the winter. Owls typically spend the winter at the burrow where they nested the previous summer or the burrow where they intend to nest the upcoming summer.

Introduction

Burrowing owls (*Athene cunicularia*) in North America have suffered population declines and significant range contraction (Dechant et al. 1999, Wellicome and Holroyd 2001). In the U.S., burrowing owls are federally listed as a species of *National Conservation Concern* (U.S. Fish & Wildlife Service 2002) and as endangered, threatened, or a species of concern in 9 states (Klute et al. 2003). Washington Department of Fish and Wildlife is currently evaluating the status of burrowing owls for consideration as a state threatened or endangered species. Prior to developing and implementing recovery efforts, we need to understand both the ultimate causes of population declines and the proximate factors influencing local distribution, reproductive success, and annual survival of burrowing owls. Burrowing owls prefer open or short-grass areas within deserts, grasslands, and shrub-steppe (Haug et al. 1993). Local population declines in relatively undisturbed shrub-steppe in Washington (Smith et al. 1997, Bartels and Tabor 1999, C. Conway, pers. observ.) suggest that conversion of native shrub-steppe to agriculture may not be the only (or even the main) cause of burrowing owl declines. For example, lack of suitable nesting burrows and reduction of prey due to the eradication of colonial burrowing mammals may also limit burrowing owl populations (Desmond and Savidge 1996).

Project Objectives

The objectives of this cooperative multi-agency project in 2003 were to:

1) Repeat standardized call-broadcast surveys along a subset of survey routes in eastern Washington to locate natural nesting burrows and facilitate estimation of population trends.
2) Determine the following demographic parameters of burrowing owls in Washington and compare these to populations in other portions of their range:
   a. nesting success;
   b. number of fledglings per nest;
   c. probability of natal recruitment;
   d. annual return rate of adult burrowing owls; and
   e. breeding and natal dispersal distances.
3) Examine the vegetative and landscape features that influence reproductive success and territory fidelity.
4) Determine the migratory status of burrowing owls in eastern Washington.
5) Examine the efficacy of using artificial burrows to restore local burrowing owl populations.
6) Estimate the proportion of burrowing owl nesting burrows that are destroyed each year in eastern Washington.

Project Partners

To accomplish these objectives, we have brought together a large number of project partners: U.S. Bureau of Land Management, U.S. Fish and Wildlife Service (Hanford Reach National Monument/Saddle Mountain National Wildlife Refuge, McNary National Wildlife Refuge, Columbia National Wildlife Refuge), Washington Department of Fish and Wildlife, University of Arizona, U.S. Geological Survey, Arizona Cooperative Fish and Wildlife Research Unit, the Inland Northwest Wildlife Council, and the Lower Columbia Basin Audubon Society. Personnel working on the project in 2003 included Kara Altvater, Victoria Garcia, Gwendolen Morgan, Chris Nadeau, Claire Sanders, Mark Southern, and Jessica Talamas. Charlotte Reep from the Lower Columbia Basin Audubon Society assisted in many aspects of the work in the Tri-Cities area.

Study Sites

This project has been underway since spring of 2000 at two study sites in eastern Washington: one in central WA and one in southern WA. The central WA study area is approximately 3600 km^2 and is located in Adams and Grant counties. The burrows are loosely concentrated in and around Moses Lake and Othello, with a few as far west as George. The majority of the study area is rural. The Tri-Cites study area is approximately 1500 km^2 and is located in Benton, Franklin, and Walla Walla counties. This study area encompasses Pasco, Kennewick, Richland, and West Richland and includes some burrows on the Arid Lands Ecology (ALE) Reserve on Hanford Reach National Monument. The majority of the study area is urban/industrial. Land ownership within both study sites varies greatly. Burrows are located on private land (e.g., farmland, yards), industrial land (e.g., Burlington Northern Railyard), city land (e.g., Port of Pasco land), county land (e.g., adjacent to roads, canals, irrigation structures), state land (e.g., Washington State University land, banks of highways), and federal land (e.g., lands managed by Bureau of Land Management and U.S. Fish and Wildlife Service).

Standardized Surveys

The project objectives required locating and monitoring natural nesting burrows in order to estimate population trends, reproductive success, nest-site fidelity, and determination of habitat features that influence reproductive success. To help locate nest burrows, we developed a standardized protocol for conducting roadside point-count surveys similar to that in Conway and Simon (2003) (Appendix 1). Roadside point-count surveys were begun in 2001 at a core location within each of the two study areas. We expanded the area surveyed outward from these core areas to cover as much of the study areas as possible. In past years, we attempted to conduct surveys along all the roads within the study area. We used 4-km (2.5-mile) segments of roadway (survey routes) as the sampling unit. Each survey route included 10 survey stations separated by approximately 0.4 km (0.25 mile). Each survey point was given a unique alphanumeric code and GPS coordinates were recorded so that we could repeat the surveys efforts in future years. Repeating these standardized survey efforts in future years will provide estimates of population trends in eastern Washington.

<u>Central WA Study Area:</u> In 2003, we did not conduct point-count surveys at any of the 695 pre-established roadside survey points (Appendix 2) due to lack of personnel. We located 18 new nest burrows incidentally and 7 new nest burrows via word of mouth in 2003. Many additional satellite or secondary burrows were also located and monitored.

<u>Southern WA Study Area:</u> In 2003, we conducted standardized point-count surveys at 48 survey stations within ALE, but we did not detect any new nest burrows during the standardized surveys. We located 9 new nest burrows incidentally and 10 new nest burrows via word of mouth in 2003. Many additional satellite or secondary burrows were also located and monitored. There are 249 pre-established roadside survey points located in southern WA (Appendix 3) that were not surveyed due to lack of personnel.

Burrow Monitoring

We visited all burrows once a week to document occupancy and estimate reproductive success. At the central WA study area we monitored 267 natural and artificial burrows from the second week of March through mid-October. At the southern WA study area we monitored 348 natural and artificial burrows from the first week of March through mid-September. Color photographs of all burrows monitored since 2000 were submitted to the Spokane BLM office. This photographic record of nest burrows will help field personnel recognize a potential burrowing owl nest and help them identify areas potentially suitable for burrowing owls.

During weekly nest visits, we first observed burrows from >100m away using binoculars to check for owl activity and then approached each burrow on foot to look for signs indicating use (i.e., pellets, feathers, nest lining) or vacancy (i.e., presence of cobwebs at burrow entrance). During these weekly visits we recorded the presumed stage of the nesting cycle, and number of adult and juvenile owls observed. We also used an infrared video probe to examine nest contents of occupied burrows. Use of the infrared probe allowed us to determine the stage of the nesting cycle and the number of eggs or juveniles present on each visit. This information will be used to estimate demographic parameters such as nesting success and annual fecundity. The infrared probe was ineffective on some occupied nest burrows due to the depth of the burrow, structural features of the tunnel, or excessive lining in the tunnel. For example, at the central WA study area the infrared probe was effective on 77% of occupied nest burrows for ≥50% of peeping attempts (effective every time for 65% of nest burrows) and ineffective on 23% of occupied nest burrows for >50% of peeping attempts.

Burrow Use and Nesting Success

Estimating reproductive success for burrowing owls is challenging because the owl's nest chamber is typically >2m underground. Hence, we developed a protocol for determining nest fate and estimating reproductive parameters given this constraint. We considered a burrow a "nest" if ≥1 burrowing owl was present on ≥2 visits between the dates the first egg was laid and the last egg hatched. Hence, even burrows defended by unpaired males that failed to attract a mate (or we failed to detect the female) were considered "nests" under this definition.

The age at which juvenile burrowing owls disperse from their natal area varies greatly among individuals; some juveniles successfully disperse as young as 40 days of age while others remain at their natal burrow past 90 days of age (V. Garcia, unpublished data). However, juveniles are thought to be capable of sustainable flight at 44 days of age (Landry 1979). Hence, we considered a nest successful if juveniles successfully dispersed (moved ≥300m from natal nest) or were present at the natal nest at 50 days of age with no known failure thereafter. If all juveniles disappeared prior to 50 days of age, we assumed that the nest had failed. Hence, estimates of the number of fledglings per nest are conservative and represent a minimum number of juveniles known to have dispersed or reached 50 days of age.

<u>Central WA Study Area:</u> At the 267 monitored burrows, there were 121 nesting attempts (4 in artificial burrows) that fit our definition of a nest (including 9 burrows at which there were second nesting attempts after the first attempt failed, although not necessarily by the same pair of owls; Table 1). We documented 4 males and 3 females that made a second nesting attempt. Of the 121 nesting attempts, 69% produced nestlings, 60% produced ≥1 fledgling (44 days of age), and 59% produced ≥1 50-day-old offspring (our definition of nesting success) (Table 1). We were able to confirm final clutch size at 34 nests and the average clutch size was 8.6 eggs (SE = 0.3, range = 4-11). At the 80 nests where hatchlings were confirmed (we believe eggs hatched at another 4 nests but we never observed nestlings), the minimum number of nestlings we could attribute to a nest averaged 5.7 (SE = 0.2, range = 1-10). At the 72 nests that had ≥1 juvenile survive to 44 days of age, the minimum number of fledglings we could attribute to a nest

averaged 4.3 (SE = 0.3, range = 1-10). At the 69 nests that had ≥1 juvenile survive to 50 days of age, the minimum number of juveniles we could attribute to a nest averaged 3.8 (SE = 0.30, range = 1-10; Table 1).

Of the 47 documented nest failures: 11 failed but we were unable to confirm that eggs were laid (many of these burrows we were unable to reach the nest chamber with the infrared video probe and there was no other evidence of laying), 11 failed for unknown reasons, 10 failed prior to egg laying, 6 were abandoned after ≥1 egg was laid (generally one adult disappeared during laying or incubation, but there was no evidence that a bird had been killed near the burrow), 4 nests under irrigation troughs failed due flooding, 2 failed due to internal collapse of the burrow, 1 failed due to mammal depredation, 1 was destroyed by construction, and 1 failed because all juveniles were hit by a vehicle. One nest was not monitored long enough to determine the fate of the nest.

<u>Southern WA Study Area:</u> At the 348 monitored burrows, there were 103 nesting attempts (9 in artificial burrows) that fit our definition of a nest (including 4 burrows at which there were second nesting attempts after the first attempt failed, although not necessarily by the same pair of owls; Table 1). We documented 7 males and 4 females that made a second nesting attempt. Of the 103 nests, 74% produced nestlings, 44% produced ≥1 fledgling (44 days of age), and 41% produced ≥1 50-day-old offspring (our definition of nesting success). At 9 nests we confirmed that ≥1 juvenile successfully dispersed from the natal area. We were able to confirm final clutch size at 17 nests and the average clutch size was 7.9 (SE = 0.5, range = 4-10). At the 61 nests where hatchlings were confirmed (we believe eggs hatched at one other nest but we never observed nestlings), the minimum number of nestlings we could attribute to a nest averaged 4.1 (SE = 0.3, range = 1-10). At the 41 nests that had ≥1 juvenile survive to 44 days of age, the minimum number of fledglings we could attribute to a nest averaged 2.6 (SE = 0.3, range = 1-8). At the 31 nests that had ≥1 juvenile survive to 50 days of age, the minimum number of juveniles we could attribute to a nest averaged 2.7 (SE = 0.4, range = 1-8).

Of the documented nest failures: 17 failed but we were unable to confirm that eggs were laid (many of these burrows we were unable to reach the nest chamber with the infrared video probe and there was no other evidence of laying), 11 failed for unknown reasons, 16 failed prior to egg laying, 1 was abandoned after ≥1 egg was laid (generally one adult disappeared during laying or incubation, but there was no evidence that a bird had been killed near the burrow), 2 were depredated (1 by an avian predator and 1 by an unknown predator), and 1 nest was run over by a vehicle.

<u>Comparison Between Study Areas:</u> The proportion of monitored burrows that were occupied by owls has been relatively constant over the 3 years at both the central WA study area (45-52%) and the southern WA study area (23-24%; Table 1). A greater proportion of artificial burrows at the southern WA study area (approximately 50% compared to 10%) accounts for the difference in burrow occupancy rates between the 2 sites. Owls appear to be more likely to use natural burrows (rather than artificial burrows) as a nest burrow. Artificial burrows are frequently used as "alternate" burrows (burrows that owls use for escape or protection when away from their nest burrow).

Nesting success was greater at the central WA study area compared to the southern WA study area ($\chi^2 = 7.4$, $P = 0.007$; central WA = 59% and southern WA = 41%). Clutch size did not differ significantly between the study areas ($t = 1.2$, $P = 0.233$; central WA = 8.6 ± 0.3 and southern WA = 7.9 ± 0.3). The average number of juveniles that hatched (at nests that produced nestlings) was greater ($t = 4.5$, $P < 0.001$) in central WA (central WA = 5.7 ± 0.2 and southern

WA = 4.1 ± 0.3). The number of offspring that survived to 44 days of age was greater ($t = 4.4$, $P = 0.000$) in central WA (central WA = 4.3 ± 0.3 and southern WA = 2.6 ± 0.3). And the number of offspring that survived to 50 days of age was greater ($t = 2.3$, $P = 0.015$) in central WA (central WA = 3.8 ± 0.3 and southern WA = 2.7 ± 0.4; Table 1). The higher nesting success and higher fecundity in central WA may be a consequence of a supplemental feeding experiment that was part of Victoria Garcia's Masters thesis (to be completed in fall of 2004).

Comparison With Other Studies: Average clutch size in WA is similar to that reported in other burrowing owl studies (6-11; Haug et al. 1993). The estimates of nesting success at the two WA study areas were similar to that reported for Oregon (53%; Green and Anthony 1989). In contrast, burrowing owl populations in New Mexico had a higher probability of nesting success (67% and 100%; Botello and Arrowhead 1996, Martin 1973, respectively). However, interpreting differences in nesting success across studies is difficult because investigators might have used different definitions of what constitutes a nest, yet authors seldom identify what definition they used. The average numbers of fledglings per successful nest at the WA study areas are different from each other, but both estimates fall within the range of other studies of migratory populations of burrowing owls (4.0 fledglings per successful nest in British Columbia and 2.2 fledglings per successful nest in New Mexico; Leupin and Lowe 2001, Botello and Arrowhead 1996, respectively).

Artificial Burrows

Artificial nest burrows have been used to provide alternate nesting sites for burrowing owls in local areas (Collins and Landry 1977, Trulio 1997b) and may provide safer nest sites than natural burrows (Wellicome et al. 1997). With the help of our project partners, we installed 217 artificial nesting burrows at the southern WA study area between 1999-2002 (130 artificial burrows on 8 golf courses plus 87 artificial burrows off golf courses). The goals were 1) to compare occupancy and reproductive success of artificial burrows on and off golf courses, and 2) to compare annual burrow fidelity and natal recruitment between artificial burrows and natural burrows.

In 2003, 3 artificial burrows on golf courses were used as nests, 1 of which was successful, and 6 artificial burrows off golf courses were used as nests, 2 of which were successful. Additionally, at the central WA study area, 4 artificial burrows (which were installed by others in years prior to the start of this study) were used as nests, 2 of which were successful. Occupancy of artificial burrows on golf courses has not increased substantially since they were initially installed (2 golf course burrows were used as nests in both 2001 and 2002).

Banding Efforts

We have trapped and banded adult and juvenile burrowing owls since 2000 in order to obtain estimates of annual survival, annual burrow fidelity, natal recruitment, and dispersal distances. All captured birds received a USFWS band and a unique ACRAFT color band.

Central WA Study Area: Over the past 4 years, we have banded 1090 burrowing owls: 332 adults (137 males and 195 females) and 758 juveniles (Table 2). In 2000, we banded 88 burrowing owls: 25 adults (11 males and 14 females) and 63 juveniles. In 2001, we banded 271 burrowing owls: 99 adults (47 males and 52 females) and 172 juveniles. In 2002, we banded 446 burrowing owls: 138 adults (58 males and 80 females) and 308 juveniles. In 2003, we banded 285 burrowing owls: 70 adults (21 males and 49 females) and 215 juveniles.

Southern WA Study Area: Over the past 4 years, we have banded 942 burrowing owls: 243 adults (122 males and 121 females) and 699 juveniles (Table 2). In 2000, we banded 76 burrowing owls: 19 adults (7 males and 12 females) and 57 juveniles. In 2001, we banded 298 burrowing owls: 80 adults (36 males and 44 females) and 218 juveniles. In 2002, we banded 282 burrowing owls: 84 adults (49 males and 35 females) and 198 juveniles. In 2003, we banded 286 burrowing owls: 60 adults (30 males and 30 females) and 226 juveniles.

Re-sights of Banded Owls In Subsequent Years

Central WA Study Area: Overall, we re-sighted 82 adults that had been banded in a previous year (49 males and 33 females) and 22 owls banded as juveniles in a previous year (16 males, 4 females, and 2 of unknown sex; Table 2). Hence, 31% of the 262 adults banded 2000-2002 have been re-sighted in a subsequent year (42% for males and 23% for females) and 4% of the 543 juveniles banded 2000-2002 have been re-sighted as breeders in a subsequent year. Although we have banded fewer adult males than females, a greater proportion of adult males have been re-sighted. Assuming a male:female sex ratio of 50:50 for juveniles, 6% of juvenile males and 2% of juvenile females have recruited into the local breeding population. Females disperse further than males in most avian taxa (Greenwood 1980), which may explain why more juvenile males return to the study area than juvenile females.

Southern WA Study Area: Overall, we have re-sighted 77 adults that had been banded in a previous year (41 males and 36 females) and 39 owls banded as juveniles in a previous year (22 males, 15 females, 2 of unknown sex; Table 2). Hence, 42% of the 183 adults banded 2000-2002 have been re-sighted in a subsequent year (45% for males and 40% for females) and 8% of the 473 juveniles banded 2000-2002 have been re-sighted as breeders in a subsequent year. Assuming a male:female sex ratio of 50:50 for juveniles, 10% of juvenile males and 6% of juvenile females have recruited into the local breeding population.

Comparison Between Study Areas: Re-sight rates were significantly greater for adults and juveniles at the southern WA study area than the central WA study area (adults: $\chi^2 = 7.4$, $P = 0.007$; juveniles: $\chi^2 = 7.2$, $P = 0.007$). We can think of 2 potential reasons for the observed difference in re-sight rates between study areas: 1) owls in southern WA may have higher annual survival. The southern WA population is less migratory (see section below on winter surveys) and resident birds may have higher survival. And the central WA study site is at the northern edge of the current breeding distribution of burrowing owls and populations near the edge of a species' range often have reduced survival; 2) owls in central WA may have a higher propensity to emigrate. Indeed, we have witnessed more birds dispersing southward (see section below on site fidelity). Differences in rates of emigration between populations make comparing estimates of annual survival difficult because the methods commonly-used to estimate annual survival (capture-recapture models) do not account for permanent emigration.

Comparison of Return Rates with Other Studies: Adult return rates of 31% (42% for males and 23% for females) for the central WA study area and 42% (45% for males and 40% for females) for the southern WA study area are comparable to estimates from other studies. Adult burrowing owl return rates for other study sites range from 12.5% in a migratory population in Saskatchewan to 81% in a resident population in California (Haug 1985, Thomsen 1971). Owl populations in both of the study areas are partially migratory (see migratory status). Adult return rates at the WA study areas are similar to those for other partially-migratory populations: 44% in New Mexico (67% for males and 22% for females) and 37% in British Columbia (Martin 1973, Haug 1993).

Comparison of Natal Recruitment with Other Studies: Juvenile recruitment rates of 4% for the central WA study area and 8% for the southern WA study area are comparable to estimates in other locations. The proportion of juvenile burrowing owls recruited into the local population varies from 1-7% for migratory populations (Haug 1985, Martin 1973, Plumpton and Lutz 1993; Saskatchewan, New Mexico, and Colorado, respectively). Juvenile recruitment is typically higher in resident populations. Although some of the adults over-winter, juveniles seldom are present during winter. Hence, juveniles can be considered fully migratory. We have found only 5 juveniles (out of 1457 banded juveniles) over-wintering at the WA study sites.

Effects of Radio Transmitters on Natal Recruitment: Of the 22 burrowing owls banded as juveniles at the central WA study area that were recruited into the population as breeders in subsequent years, 7 of them were radio-collared juveniles (the other 15 were banded but did not have radio collars). Hence, 5% of juveniles that were radio-collared and 4% of juveniles that were not radio collared returned as breeders. Although sample sizes are still small, radio collars do not appear to adversely affect juvenile survival and recruitment (Conway and Garcia, *In Press*). None of the radio-collared juveniles have been detected during winter surveys. Therefore, radio collars do not appear to cause juveniles to over-winter.

Site Fidelity and Dispersal Distances

Central WA Study Area: Of the adult males that returned to the study area to breed the following year (including adults originally banded as juveniles that returned as second-year and third-year breeders), 58% (38 of 65) returned to the same burrow. Mean dispersal distance was 795 ± 418 meters (*n*=65) including males that returned to the same burrow or 1891 ± 987 meters (*n*=27) excluding males that returned to the same burrow. Of the adult females that returned to the study area to breed the following year, 41% (15 of 37) returned to the same burrow. Mean dispersal distance was 1146 ± 341 meters (*n*=36) including females that returned to the same burrow or 1965 ± 397 meters (*n*=21) excluding females that returned to the same burrow. One female moved to the southern WA study area and was not included in the analysis..

Of the juveniles that returned to the study area as breeders in a subsequent year, 21% (4 of 19) returned to breed in their natal burrow. This excludes juveniles that were not re-sighted the year following their banding since they may have returned as a first-year breeder but not have been re-sighted. Mean natal dispersal distance was 5892 ± 132 meters (*n*=19) including individuals that returned to their natal burrow or 7463 ± 4115 meters (*n*=15) excluding juveniles that returned to their natal burrow.

Southern WA Study Area: Of the adult males that returned to the study area to breed the following year (including adults originally banded as juveniles that returned as second-year and third-year breeders), 39% (21 of 54) returned to the same burrow. Mean dispersal distance was 577 ± 180 meters (*n*=54) including males that returned to the same burrow or 973 ± 284 meters (*n*=33) excluding males that returned to the same burrow. Of the adult females that returned to the study area to breed the following year 30% (13 of 44) returned to the same burrow. Mean dispersal distance was 458 ± 119 meters (*n*=44) including females that returned to the same burrow or 650 ± 150 meters (*n*=31) excluding females that returned to the same burrow.

Of the juveniles that returned to the study area as breeders in a subsequent year, 3% (1 of 33) returned to breed in their natal burrow. This excludes juveniles that were not re-sighted the year following their banding since they may have returned as a first-year breeder but not have been re-sighted. Mean natal dispersal distance was 21150 ± 4439 meters (*n*=33) including juveniles that returned to the same burrow or 12530 ± 4835 meters (*n*=32) excluding juveniles that returned to the same burrow. .

Movement Between the Study Areas: Five (4 females and 1 male) owls banded as juveniles at the southern WA study area have been re-sighted at the central WA study area. This includes 3 juveniles banded in 2002 in southern WA that were re-sighted in 2003 in central WA, 1 juvenile banded in 2001 in southern WA that was re-sighted in 2002 in central WA, and 1 juvenile in southern WA banded in 2000 that was re-sighted in 2003 in central WA. In contrast, only one owl (male) banded as a juvenile at the central WA study area in 2002 has been re-sighted as a breeder at the southern WA study area in 2003.

Two adult owls (both females) moved from central WA to southern WA after a failed nesting attempt. One female that was banded at the central WA study area in 2002 was re-sighted later in 2002 at the southern WA study area after a failed breeding attempt at the central WA study area. She returned to nest at the same burrow at the southern WA study area in 2003. One female that was banded at the central WA study area in 2003 was re-sighted later in 2003 at the southern WA study area after a failed breeding attempt at the central WA study area.

Comparison Between Study Areas: We did not detect any difference in burrow fidelity between males and females at either study area (central WA: $\chi^2 = 1.46$, $P = 0.227$; southern WA: $\chi^2 = 0.895$, $P = 0.344$). There was also no difference in burrow fidelity detected between the southern WA study area and the central WA study area for either males or females (males: $\chi^2 = 2.28$, $P = 0.131$; females: $\chi^2 = 0.703$, $P = 0.402$). Juveniles at the central WA study area did have higher burrow fidelity compared to juveniles at the southern WA study area ($\chi^2 = 5.64$, $P = 0.017$).

We failed to detect a difference in dispersal distance between males and females at either study area ($t = -1.0$, $P = 0.262$ and $t = 1.0$, $P = 0.323$ for central and southern WA, respectively). We failed to detect a difference in juvenile natal dispersal distance between the two study sites ($t = -0.7$, $P = 0.510$).

Measurement of Habitat Features at Nests

Previous studies of burrowing owls in other regions have shown that certain habitat features influence burrow occupancy or success (Trulio 1997, Warnock and Skell 2002). We measured a suite of habitat and landscape features at occupied burrows to identify potential features that differentiate successful from unsuccessful burrows. Because we measured additional habitat parameters in each year of the study, the sample size is not the same for all habitat features in the analyses. Habitat features included were:

1) **Vegetation (grasses, trees/shrubs, and forbs) within a 30-meter radius of the burrow** to determine if amounts of native vegetation, non-native vegetation, or total area covered by vegetation differs between successful and unsuccessful burrows.
2) **Land use within a 100-meter radius of the burrow** to determine if specific land uses are associated with successful vs. unsuccessful burrows.
3) **Burrow features** (type of burrow, orientation of burrow, maximum and minimum diameter of burrow opening, maximum and minimum diameter within burrow, height of mound, and maximum and minimum diameter of mound) to determine if specific burrow features are associated with successful vs. unsuccessful burrows.
4) **Surrounding landscape features** (number of usable burrows within a 30-meter radius of the burrow, distance to the nearest perch, distance to the nearest paved road, distance to the nearest gravel road, traffic frequency index of nearest road, speed limit of the nearest road,

percent of overhead cover within a 30-meter radius of the burrow, distance to the nearest available shade, and distance to the nearest building) to determine if specific landscape features are associated with successful vs. unsuccessful burrows.

5) **Burrow visibility** (visibility at 1 meter height at distances of 10 and 30 meters from burrow from 8 cardinal directions) to determine if visibility of the owl (e.g., by a predator) perched on the mound is associated with successful vs. unsuccessful burrows.
6) **Soil types** at occupied burrows from 2000 to 2003 were analyzed by the BLM Spokane office to determine if burrowing owls have greater success in burrows in certain types of soil.

We used 2-tailed *t*-tests to compare each of these variables (except for the type of burrow and orientation of burrow) between successful and unsuccessful nest burrows. We used chi-squared goodness-of-fit tests to determine if orientation of the nest burrows were proportionately distributed across the 4 cardinal directions and if orientation of the nest burrows differed between successful and unsuccessful nests.

Central WA Study Area: We detected no differences between successful and unsuccessful burrows in the percent of land covered by native vegetation, non-native vegetation, or total vegetation within a 30-meter radius of the burrow (Table 3). However, successful burrows tended to have less native vegetation cover and less total vegetation cover than unsuccessful burrows.

Agriculture was the land use encountered at the greatest proportion (65%) of occupied burrows (Table 4). Paved road (32%), gravel road (20%), and pasture (19%) were also commonly-encountered land uses near nest burrows. Gravel roads accounted for a significantly higher percent of land use within a 100-m radius of successful vs unsuccessful burrows. Burrows near pastures were more likely to be successful and burrows near agriculture and irrigations canals were less likely to be successful, but these differences were only marginally significant. Successful burrows had higher percentage of shrub-steppe compared to unsuccessful burrows, but the difference was not statistically significant.

Burrowing owls in the central WA study area used abandoned badger burrows most frequently (45% of all nest burrows; Figure 1). Many occupied burrows were associated with various man-made structures.

We found some evidence that burrowing owls chose nest burrows that face north and east and avoid burrows that face south and west (Table 5). However, we failed to detect any difference in burrow orientation between successful and unsuccessful nests. We found little evidence that the burrow features, surrounding landscape features, or visibility differs between successful and unsuccessful nest burrows (Tables 6, 7, and 8). Successful burrows tended to be further from buildings, less visible (from fewer directions; Table 8), have shallower mounds, have a larger minimum diameter opening and have more burrows surrounding them.

Thirty-two types of soils were found at burrows occupied in 2000-2003 (Figure 2). Malaga stony sandy loam (0 to 15% slopes) was the most common type of soil, found at 13% of burrows.

Southern WA Study Area: We detected no differences between successful and unsuccessful burrows in the percent of land covered by native vegetation, non-native vegetation, or total vegetation within a 30-meter radius of the burrow (Table 9).

Abandoned field was the land use encountered at the greatest proportion (78%) of occupied burrows (Table 10). Paved road (40%), shrub-steppe (31%), and railway (19%) were also commonly-encountered land uses near nest burrows. Burrows near railways (Pasco

Railyard) tended to be more successful and burrows near roads (paved and gravel) tended to be less successful, but these differences were not statistically significant.

Burrowing owls in the southern WA study area use abandoned badger burrows most frequently (43% of all nest burrows; Figure 1).

We failed to detect any deviation from random in the orientation of nest burrows or any difference in burrow orientation between successful and unsuccessful nests (Table 11). We found little evidence that burrow features, surrounding landscape features, or visibility differs between successful and unsuccessful burrows (Tables 12, 13, and 14). Successful burrows tended to have shallower mounds, have more burrows surrounding them, and were closer to perches while unsuccessful burrows were near roads with more traffic.

Fourteen types of soils were found at burrows occupied in 2000-2003 (Figure 3). Burbank loamy fine sand (0 to 15% slopes) was the most common type of soil, found at 21% of burrows.

Juvenile Movements

At the central WA study area, we recorded the age that juvenile burrowing owls leave their natal burrow and the factors that influence the timing of this movement. To do this, we radio-collared 83 juveniles from 67 nests in 2003 to track their movements. Of the 83 transmittered birds, 31 died prior to leaving their natal burrow, 34 left their natal burrow (3 of which later died), we lost the signal on 15 birds (we suspect they dispersed but could not confirm), and 3 had unknown fates. To determine if prey abundance influences the age of natal dispersal, we provided supplemental food at a random sample of nests and live-trapped small mammals and pit-trapped insects at each control nest twice during the nesting cycle. To determine if flea load influences the age of natal dispersal, we treated a random sample of nests with diatomaceous earth to desiccate invertebrates. This component of the study is part of a M.S. thesis by Victoria Garcia and she is currently analyzing her data. She plans to finish her thesis in the fall of 2004.

Salvage of Dead Owls

<u>Central WA Study Area:</u> In 2003, we found 84 dead burrowing owls: 6 adults (3 males, 2 females, 1 of unknown sex), 66 juveniles, and 12 owls of unknown age and sex. We attempted to assign cause of mortality for each bird based on the remains. We typically found remainsonly very close to the nest burrow and often those remains were insufficient to assign cause of death. Of the 6 adults, 1 male was killed by a vehicle, and the other 5 died of unknown causes. Of the 66 juveniles, 13 were killed by an avian predator, 11 were killed by a terrestrial predator, 19 were killed by vehicles, 1 died of starvation, 1 drowned, and 21 died of unknown causes. Of the 12 owls of unknown age or sex, 3 were killed by a terrestrial predator, 1 was killed by an avian predator, and 8 died of unknown causes.

<u>Southern WA Study Area:</u> In 2003, we found 27 dead burrowing owls: 6 adults (4 males, 2 females), 15 juveniles, and 6 owls of unknown age and sex. Of the 6 adults, 1 female was killed by a vehicle, 1 male was killed by a terrestrial predator and the other 4 died of unknown causes. Of the 17 juveniles, 1 was killed by an avian predator, 2 were killed by a terrestrial predator, 2 were hit by a vehicle, 1 died of starvation, 1 appeared to have hit a wall, 2 were juveniles from previous years that appeared to have been removed from the burrow by its current occupants, and 8 died of unknown causes. Of the 4 owls of unknown age and sex, all 4 died of unknown causes.

Comparison Between Study Areas: The same number of dead adult owls were found at each study area. A much larger number of juveniles was found at the central WA study area (66) than the southern WA study area (15) because we were following radio-marked juveniles in central WA. Based on the estimates of the number of nestlings per nest compared to the fledglings per nest, the sites have 33% (central WA) and 34% (southern WA) mortality of young prior to fledging, or roughly 150 juveniles per study area. Therefore, there are many juveniles for whom we do not find any remains or indication of mortality. Of the 66 juveniles found at the central WA study area, 34 were radio-collared juveniles. Radio-collaring juveniles has allowed us to locate carcasses that we would not otherwise have found, such as those that died far from the natal burrow or that had few or inconspicuous remains.

Migratory Status

Although most of the burrowing owls in Washington spend their winters elsewhere, some individuals at both study areas are year-round residents. We conducted winter re-sight surveys to determine the proportion of breeding owls that over-winter on both study areas in the winters of 2001-02, 2002-03, and 2003-04. We estimated the percentage of banded owls over-wintering at each of the Washington study areas by visiting all nest sites twice during December and/or January. These estimates are conservative because we obviously missed some owls during the 2-week winter surveys and an unknown proportion of adults banded during the previous breeding season had undoubtedly emigrated or died.

Central WA Study Area: We detected 16 owls in the study area during the 2001-02 winter survey (Table 15). Of the 16 owls detected, 9 (all males) were banded, 5 were unbanded, and we could not observe the legs adequately enough on 2 birds to determine whether or not they were banded. Hence, 9% of the banded adults (19% of the banded adult males) in the study area during the breeding season of 2001 were present during the winter of 2001-02. One of the banded owls present during the 2001-02 winter survey was observed at his 2001 nest burrow and he also nested at this burrow in 2002. Five owls were at burrows less than 1 km from where they had bred in 2001. We were unable to get a complete read on the band for the remaining 3 banded males. Two of the 6 banded owls used the burrow where they were detected during the 2001-02 winter survey as their nest burrow in 2002. One male nested at a burrow less than 150 meters away from the burrow he was using during the 2001-02 winter survey. The other 3 banded males observed during the winter survey were not re-sighted during the breeding season of 2002.

We detected 21 owls in the study area during the 2002-03 winter survey (Table 15). Of the 21 owls detected, 9 were banded (6 males, 1 female, and 2 hatch-year birds), 8 were unbanded, and we could not observe the legs adequately enough on 4 birds to determine whether they were banded. Hence, 5% of the banded adults (8% of the banded adult males and 1% of the banded adult females) in the study area during the breeding season of 2002 were present during the winter of 2002-03. One percent of banded hatch-year birds present during the breeding season of 2002 were present during the winter of 2002-03. The 2 hatch-year birds that spent the winter were not radio-collared birds. Of the 7 banded adult owls present during the 2002-03 winter survey, 6 were over-wintering at the burrow at which they nested in 2002. The other banded adult was at a burrow less than 1 km from where he had bred in 2002. One of the hatch-year birds was far (~1.5 km) from its natal burrow. We aren't sure how far the other hatch-year bird moved because we couldn't get a complete read on the band during the winter survey (we could tell he was a hatch year bird because of the color and location of its band).

Southern WA Study Area: We detected 17 owls in the study area during the 2001-02 winter survey (Table 15). Of the 17 owls detected, 5 were banded (4 males, 1 female), 6 were unbanded, and we could not observe the legs adequately enough on 6 birds to determine whether or not they were banded. Hence, 9% of the banded adults (17% of the banded adult males and 3% of the banded adult females) present during the breeding season of 2001 were also present during the winter of 2001-02. All 5 of the banded owls present during the 2001-02 winter survey were observed at their 2001 nest burrow. This includes a banded female who was over-wintering with her mate at their 2001 nest burrow and which they used again in 2002. Three of the 5 banded owls used the burrow where they were detected during the 2001-02 winter survey as their nest burrow in 2002. The other 2 males nested at burrows approximately 100 meters and 1 km away from where they were detected during the winter survey.

We detected 31 owls in the study area during the 2002-03 winter survey (Table 15). Of the 31 owls detected, 18 were banded (13 males, 2 females, and 3 hatch-year birds), 10 were unbanded, and we could not observe the legs adequately enough on 3 birds to determine whether or not they were banded. Hence, 12% of the banded adults (21% of the banded adult males and 3% of the banded adult females) present during the breeding season of 2002 were also present during the winter of 2002-03. Two percent of banded hatch-year birds present during the breeding season of 2002 were present during the winter of 2002-03. One owl banded as a juvenile in 2001 returned as a breeder in 2002 and was re-sighted during the 2002-03 winter survey. Thirteen of the 15 banded adult owls detected during the winter survey were over-wintering at the burrow where they nested in 2002. This includes 2 banded females who were over-wintering with their mates at their 2002 nest burrow. The 2 remaining males were at burrows 200 meters and 5 km away from the burrows where they had bred in 2002. One of the hatch-year birds was at its natal burrow, and the other 2 were about 2.5 km from their natal burrows. Two of the males present during the 2002-2003 winter survey bred in the study area in 2001 and 2002 and were present for both the 2001-02 and 2002-03 winter surveys (one also bred in the study area in 2000).

We detected 27 owls in the study area during the 2003-04 winter survey (Table 15). Of the 27 owls detected, 15 were banded (12 males, 1 female, and 2 hatch-year birds), 10 were unbanded, and we could not observe the legs adequately enough on 2 birds to determine whether or not they were banded. Hence, 10% of the banded adults (17% of the banded adult males and 2% of the banded adult females) present during the breeding season of 2003 were also present during the winter of 2003-04. One percent of the banded hatch-year birds present during the breeding season of 2003 were present during the winter survey of 2003-04. One of the over-wintering adult females has bred at the southern WA study area (at the same burrow and with the same male) for the past three years. She was also present during the 2002-03 winter survey. During the winter of 2002-03, she over-wintered with her mate at their nest burrow. This past winter she was over-wintering 900m from her nest burrow, and her 2003 mate was over-wintering at their nest burrow. The percentage of adults and hatch-year birds over-wintering at the southern WA study area has remained relatively constant from 2001-02 to 2002-03 to 2003-04.

Comparison Between Study Areas: A greater proportion of owls over-winter on the southern WA study area compared to the central WA study area. This difference is probably due to a warmer winter climate or a more stable food source in the more urban setting of the southern WA study area.

Proposed Research Schedule for 2004

In the coming year, we plan to again monitor potential nest burrows in eastern Washington from mid-March through September 2004 to quantify occupancy and reproductive success of burrowing owls. We plan to continue banding and re-sighting adults and juveniles so that we can obtain estimates of annual survival of adults and natal recruitment of juveniles. We plan to collect a feather sample from each owl so that we might estimate annual rates emigration into Washington using stable isotope signatures. This could potentially allow us to correct for breeding dispersal bias when estimating annual survival. We plan to conduct roadside point-count surveys at a subset of the established points to help locate banded birds that may have dispersed to new nest burrows. We hope to conduct winter surveys again during the winter of 2004-05 at both study areas.

Management Recommendations

Many believe that burrowing owls have declined in the state of Washington, but we currently lack estimates of the magnitude of population change. We urge management agencies to put resources toward an annual or bi-annual standardized survey that would provide estimates of population status and trends. Potential nest burrows are being destroyed each year in eastern Washington and preventing declines depends partly on maintaining available nest burrows. Many areas that have available nest burrows (especially those that owls currently use; Appendix 4-5) have now been identified and these areas should be protected and current management practices in those areas should be maintained. Many burrows are being destroyed in southern WA due to urban development. All developments proposed within the burrowing owl range in Washington should be scrutinized and developers should be required to conduct 3 surveys for burrowing owls between early April and mid-July using established standardized survey methods.

Some burrowing owls spend the entire year in eastern Washington and the burrows used by owls during winter months are often used as nest burrows the following year. The same burrows are often used in successive years by nesting owls. Hence, protecting burrows that are used any time of year is important for maintenance of the breeding population. Even with preservation of existing nesting areas, the number of available burrows will decline because burrows collapse over time. Creation of new burrows is important for preventing further declines in burrowing owls in eastern Washington. Ground squirrels, marmots, and badgers continually create new burrows that eventually become available as nest sites for burrowing owls. Creation of artificial burrows does not appear to be a method by which we can mitigate loss of potential nest burrows created by fossorial mammals. Preventing further eradication of these fossorial mammal populations in eastern Washington should be a management priority to prevent future declines in burrowing owls. We also recommend reintroducing populations of ground squirrels to areas where they have disappeared.

Burrowing owls in Washington are attracted to areas that support ranching or agriculture (presumably because prey abundance is higher in these areas compared to other land uses or because these land uses are more common in areas with deeper soils that can support burrow systems on which the owls depend). Most of the nests we have found are on private lands. Many private landowners that we interact with in eastern Washington enjoy having nesting owls on their property (or are at least indifferent to their presence), but make concerted efforts to eradicate fossorial mammals. Working with farmers and ranchers who have burrowing owls nesting on their lands should be a priority. A multi-agency effort may be needed that focuses on education, outreach, and compensation to encourage private landowners to maintain fossorial mammal populations and preserve potential nest burrows on their land.

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Biology and conservation of owls of the Northern Hemisphere. U.S.D.A. Forest Service, General Technical Report NC-190, St. Paul, MN.

Table 1. Occupancy and success of nests at the central WA and southern WA study areas in 2003.

	Central WA	Southern WA
# of burrows monitored	267	348
# of nest burrows (% of monitored burrows)	121 (45%)	103 (23%)
Average clutch size (*n*)	8.6 ±0.3 (34)	7.9 ±0.5 (17)
# of nests that produced nestlings (% of nests)	84 (69%)	62 (74%)
Average # of young that hatched/nest for nests that produced nestlings (*n*)	5.7 ± 0.22 (80)	4.1 ± 0.28 (61)
# of nests where ≥1 juvenile reached 44 days of age (% of nests)	72 (60%)	45 (44%)
Average # of young at natal burrow/nest at 44 days of age[1] (*n*)	4.3 ± 0.26 (72)	2.6 ± 0.28 (41)
# of nests that were successful (≥1 juv reached 50 days of age) (% of nests)	71 (59%)	42 (41%)
Average # of young at natal burrow/nest at 50 days of age[2] (*n*)	3.8 ± 0.3 (69)	2.7 ± 0.4 (31)

[1]Only includes nests that had ≥1 offspring survive to 44 days of age
[2]Only includes nests that had ≥1 offspring survive to 50 days of age

Table 2. Summary of 2000-2003 banding and re-sight information for burrowing owls at the central WA and southern WA study areas.

		Central WA	Southern WA
2000	Adults banded	25	19
	Males	11	7
	Females	14	12
	Hatch-year owls banded	63	57
2001	Adults banded	99	80
	Males	47	36
	Females	52	44
	Hatch-year owls banded	172	218
2002	Adults banded	138	84*
	Males	58	49*
	Females	80	35
	Hatch-year owls banded	308	198
2003	Adults banded	70	60
	Males	21	30
	Females	49	30
	Hatch-year owls banded	215	226
	Total # of adults re-sighted in subsequent year	82 (31%)	77 (42%)
	Males	49 (42%)	41 (45%)
	Female	33 (23%)	36 (40%)
	Total # juv owls re-sighted in subsequent year	22 (4%)	39 (8%)
	Males**	16 (6%)	22 (10%)
	Female**	4 (2%)	15 (6%)
	Unknown	2	2

*includes two males banded during winter survey
**assumes a 50:50 sex ratio

Table 3. Vegetation cover within a 30-m radius of nests at the central WA study area. Included are the average percent of cover of native vegetation, non-native vegetation, and total vegetation for successful and unsuccessful burrows, and *t*-tests comparing successful vs. unsuccessful burrows.

Species	Average % cover at successful burrows (*n*=62)	Average % cover at unsuccessful burrows (*n*=45)	*t*	df	*P*
Native vegetation	11.3 ± 2.0	7.7 ± 1.6	-1.4	104.1	0.166
Non-native vegetation	45.0 ± 3.6	39.2 ± 4.3	-1.0	105	0.300
Total vegetation	56.3 ± 3.9	46.9 ± 4.7	-1.5	105	0.124

Table 4. Land use within a 100-m radius of nests at the central WA study area including the proportion of occupied burrows with each land use present, the average percent of land under each use for successful and unsuccessful burrows, and *t*-tests comparing successful vs unsuccessful burrows.

Land use	Percent of occupied burrows with land use	Average % cover at successful burrows (*n*=66)	Average % cover at unsuccessful burrows (*n*=13)	*t*	df	*P*
Agriculture	65%	37.4 ± 5.8	49.3 ± 6.8	1.3	77	0.186
Paved road	32%	5.7 ± 2.0	6.6 ± 1.9	0.3	77	0.740
Gravel road	20%	2.8 ± 0.8	0.9 ± 0.4	-2.1	62.9	**0.043**
Pasture	19%	19.0 ± 5.1	6.9 ± 3.8	-1.9	75	0.062
Abandoned field	17%	8.2 ± 3.7	16.7 ± 6.1	1.9	57.5	0.236
Irrigation canal	15%	0.9 ± 0.4	2.1 ± 0.8	1.3	50.2	0.207
Shrub-steppe	11%	9.1 ± 3.9	4.3 ± 3.0	-0.9	77	0.354
Railway	8%	0.8 ± 0.6	2.1 ± 1.1	1.1	52.1	0.291
Housing	4%	0.8 ± 3.7	0.1 ± 0.8	-1.1	48.5	0.266
Industry	4%	0.6 ± 0.4	0.6 ± 0.6	0.01	77	0.996
Airport	3%	1.6 ± 1.6	1.1 ± 1.1	-0.2	77	0.828
Vacant lot	1.3%	1.1 ± 1.1	0	-0.9	77	0.376
Feed storage	1.3%	0.68 ± 0.7	0	-0.9	77	0.376

Figure 1. Type of burrow for burrowing owl nests in Washington.

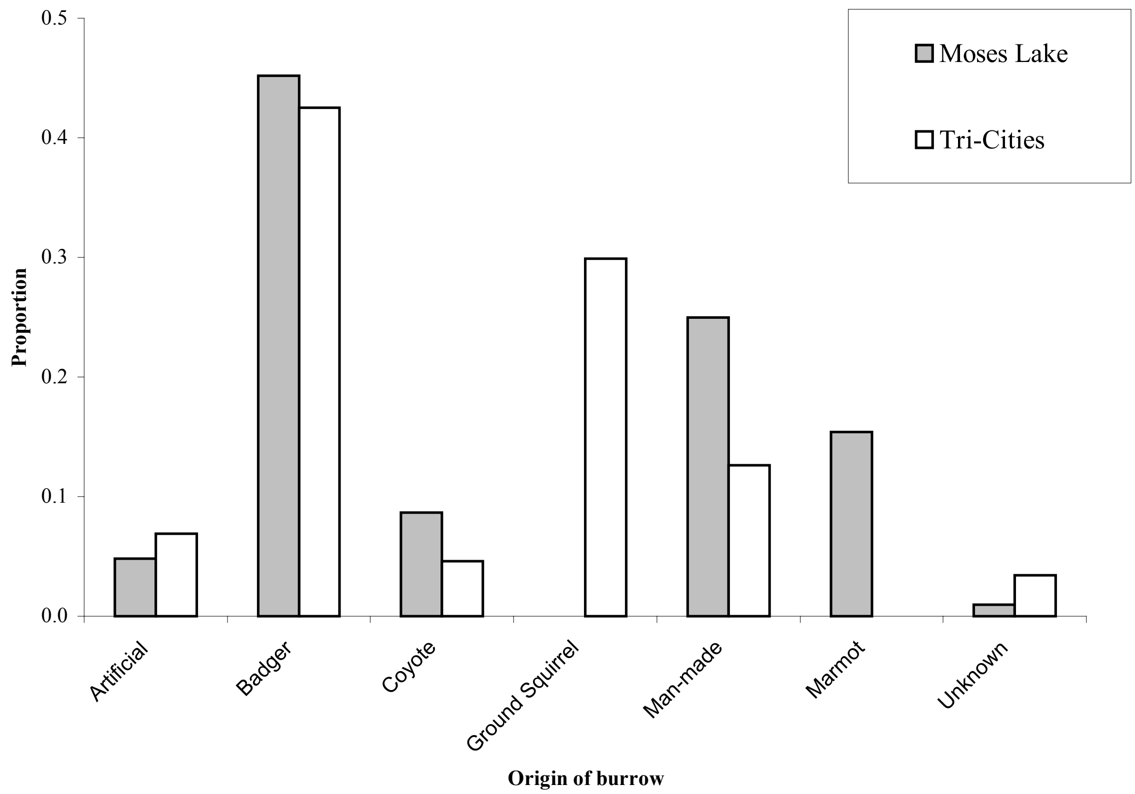

Table 5. Orientation of nests at the central WA study area and a chi-square test examining whether orientation of occupied nest burrows was random ($\chi^2 = 7.2$, df = 3, $P = 0.065$) and whether orientation of the nest burrow affected probability of success ($\chi^2 = 1.1$, df = 3, $P = 0.777$).

Orientation	Nests (n=47)	Percent of nests	# of successful nests (n=27)
North	18	38.3%	10
East	14	29.8%	10
South	6	12.8%	2
West	9	19.1%	5

Table 6. Average dimensions of successful and unsuccessful nest burrows at the central WA study area and *t*-tests comparing successful vs. unsuccessful burrows.

Variable (cm)	Average for successful burrows	*n*	Average for unsuccessful burrows	*n*	*t*	df	*P*
Minimum diameter of opening	23.8 ± 1.4	58	20.8 ± 1.7	43	-1.4	99	0.163
Maximum diameter of opening	28.8 ± 1.8	58	27.4 ± 1.8	43	-0.5	99	0.590
Minimum diameter of tunnel	16.6 ± 0.9	51	18.1 ± 1.8	37	0.8	86	0.413
Maximum diameter of tunnel	23.3 ± 1.7	52	22.6 ± 2.6	36	-0.2	86	0.829
Height of mound	15.3 ± 2.1	53	25.7 ± 6.3	36	1.6	87	0.123
Minimum diameter of mound	72.9 ± 6.4	53	66.9 ± 11.2	36	-0.5	87	0.607
Maximum diameter of mound	92.3 ± 8.3	53	91.3 ± 15.0	36	-0.1	87	0.935

Table 7. Features of the surrounding landscape for successful and unsuccessful nest burrows at the central WA study area and *t*-tests comparing successful vs. unsuccessful burrows.

Variable (m except where noted)	Average for successful burrows	*n*	Average for unsuccessful burrows	*n*	*t*	df	*P*
# of burrows within 30m	2.2 ± 0.4	60	1.4 ± 0.3	43	-1.8	93.5	0.078
Distance to nearest perch	55.3 ± 16.9	61	58.3 ± 19.7	43	0.1	102	0.909
Distance to nearest paved road	286.2 ± 37.3	61	297.4 ± 49.4	45	0.2	104	0.854
Distance to nearest gravel road	458.0 ± 78.6	51	393.0 ± 68.1	34	-0.6	83	0.561
Index of nearest road (1-5)	2.3 ± 0.2	62	2.3 ± 0.1	45	0.07	104.7	0.947
Speed limit of nearest road (mph)	46.5 ± 1.8	61	46.9 ± 1.6	43	0.2	102	0.877
Percent overhead cover within 30m	45.7 ± 4.9	46	43.9 ± 5.7	34	-0.2	78	0.818
Distance to nearest shade	50.9 ± 31.6	62	36.7 ± 24.2	43	-0.3	103	0.743
Distance to nearest building	443.9 ± 43.4	63	385.3 ± 31.2	45	-1.0	106	0.276

Table 8. Average number of the 8 cardinal directions from which nests were visible at 10-m distance from the burrow and 30-m distance from the burrow at the central WA study area including *t*-tests comparing successful vs. unsuccessful burrows.

Distance	Average # of directions visible at successful burrow (*n*=59)	Average # of directions visible at unsuccessful burrows (*n*=43)	*t*	df	*P*
10 meters	4.1 ± 0.3	4.7 ± 0.4	1.3	100	0.199
30 meters	3.4 ± 0.3	4.1 ± 0.4	1.3	100	0.193

Figure 2. Soil types of occupied burrows for 2000-2003 at the central Washington sudy area.

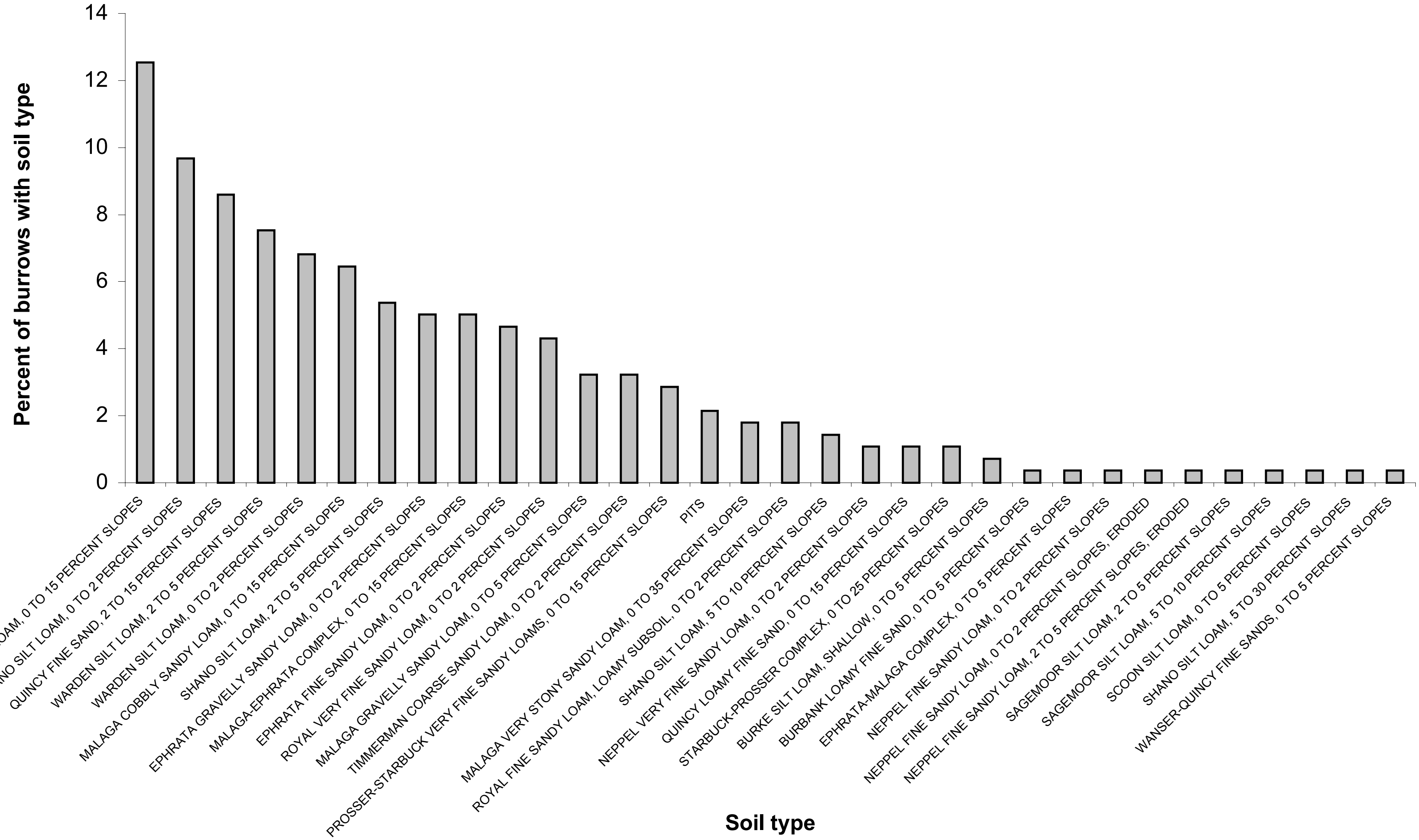

Table 9. Vegetation cover within a 30-m radius of nests occupied in 2003 at the southern WA study area. Included are the average percent of cover of native vegetation, non-native vegetation, and total vegetation for successful and unsuccessful burrows, and *t*-tests comparing successful vs. unsuccessful burrows.

Species	Average % cover at successful burrows (*n*=38)	Average % cover at unsuccessful burrows (*n*=52)	*t*	df	*P*
Native vegetation	25.3 ± 2.7	22.01 ± 1.8	-1.1	88	0.290
Non-native vegetation	51.8 ± 3.3	54.6 ± 2.5	0.7	88	0.489
Total vegetation	77.1 ± 3.0	76.7 ± 2.3	-0.1	88	0.909

Table 10. Land use within a 100-m radius of nests at the southern WA study area including the proportion of occupied burrows with each land use present, the average percent of land under each use for successful and unsuccessful burrows, and *t*-tests comparing successful vs. unsuccessful burrows.

Land use	Percent of occupied burrows with land use	Average % cover at successful burrows (n=36)	Average % cover at unsuccessful burrows (n=45)	t	df	P
Abandoned field	78%	55.4 ± 5.6	49.8 ± 5.4	-0.7	79	0.482
Paved road	40%	5.4 ± 1.5	9.1 ± 2.9	1.1	79	0.296
Shrub-steppe	31%	15.8 ± 4.1	15.5 ± 4.0	-0.1	79	0.957
Railway	19%	7.5 ± 2.5	2.8 ± 1.2	-1.8	79	0.075
Gravel road	14%	0.8 ± 0.4	9.1 ± 2.9	1.2	79	0.247
Industry	14%	3.6 ± 1.7	3.4 ± 1.5	0.3	79	0.910
Housing	11%	2.5 ± 1.4	3.3 ± 2.3	0.3	79	0.769
Agriculture	7%	1.1 ± 0.8	1.6 ± 1.0	0.3	79	0.751
Golf Course	6%	1.0 ± 1.0	2.4 ± 1.4	0.8	79	0.402
Pasture	4%	0.6 ± 0.6	0.3 ± 0.3	-0.4	79	0.696
Vacant lot	2.50%	1.9 ± 1.9	1.5 ± 1.5	-0.2	79	0.875
Airport	1.20%	0 ± 0	2.0 ± 1.9	0.9	79	0.374

Table 11. Orientation of nests at the southern WA study area and a chi-square test examining whether orientation of occupied nest burrows was random ($\chi^2 = 3.8$, df = 3, $P = 0.279$) and whether orientation of the nest burrow affected probability of success ($\chi^2 = 0.3$, df = 3, $P = 0.953$).

Orientation	Nests (n=26)	Percent of nests	# of successful nests (n=7)
North	3	12%	1
East	10	38%	2
South	7	27%	2
West	6	23%	2

Table 12. Average dimensions of successful and unsuccessful nest burrows at the southern WA study area and *t*-tests comparing successful vs. unsuccessful burrows.

Variable (cm)	Average for successful burrows	*n*	Average for unsuccessful burrows	*n*	*t*	df	*P*
Minimum diameter of opening	17.8 ± 1.0	38	19.1 ± 1.0	52	0.9	88	0.378
Maximum diameter of opening	28.0 ± 1.9	38	25.4 ± 1.1	52	-1.3	88	0.207
Minimum diameter of tunnel	13.5 ± 0.8	38	14.2 ± 4.4	49	0.7	85	0.465
Maximum diameter of tunnel	23.9 ± 2.1	38	20.9 ± 1.0	49	-1.3	53.8	0.195
Height of mound	10.6 ± 1.2	37	15.6 ± 2.3	52	1.7	87	0.093
Minimum diameter of mound	119.8 ± 8.3	38	115.7 ± 5.6	38	-0.4	88	0.671
Maximum diameter of mound	168.8 ± 11.0	38	157.8 ± 10.4	52	-0.7	88	0.475

Table 13. Features of the surrounding landscape for successful and unsuccessful nest burrows at the southern WA study area and *t*-tests comparing successful vs. unsuccessful burrows.

Variable (m except where noted)	Average for successful burrows	*n*	Average for unsuccessful burrows	*n*	*t*	df	*P*
# of burrows within 30m	2.3 ± 0.7	38	1.3 ± 0.4	52	-1.4	57.6	0.179
Distance to nearest perch	8.1 ± 1.6	37	13.0 ± 3.0	48	1.4	83	0.173
Distance to nearest paved road	149.2 ± 18.8	38	174.7 ± 23.3	53	0.8	89	0.425
Distance to nearest gravel road	207.5 ± 72.5	19	206.4 ± 46.2	35	-0.01	52	0.989
Index of nearest road (1-5)	2.7 ± 135	38	3.1 ± 0.2	52	1.6	88	0.105
Speed limit of nearest road (mph)	36.0 ± 2.0	34	39.4 ± 2.2	49	1.1	80.5	0.257
Percent overhead cover within 30m	14.1 ± 1.5	43	14.1 ± 2.0	44	1.0	85	0.317
Distance to nearest shade	11.1 ± 4.1	37	9.0 ± 2.0	35	-0.4	70	0.656
Distance to nearest building	200.2 ± 28.0	40	250.6 ± 33.5	45	1.1	83	0.258

Table 14. Average number of the 8 cardinal directions from which nests were visible at 10-m distance from the burrow and 30-m distance from the burrow southern WA study area including *t*-tests comparing successful vs. unsuccessful burrows.

Distance	Average directions visible at successful burrow (*n*=35)	Average directions visible at unsuccessful burrows (*n*=51)	*t*	df	*P*
10 meters	5.1 ± 0.5	5.0 ± 0.4	-0.3	84	0.794
30 meters	3.3 ± 0.4	3.4 ± 0.4	0.2	84	0.846

Figure 3. Soil types of occupied burrows for 2000-2003 at the Southern Washington Study Area

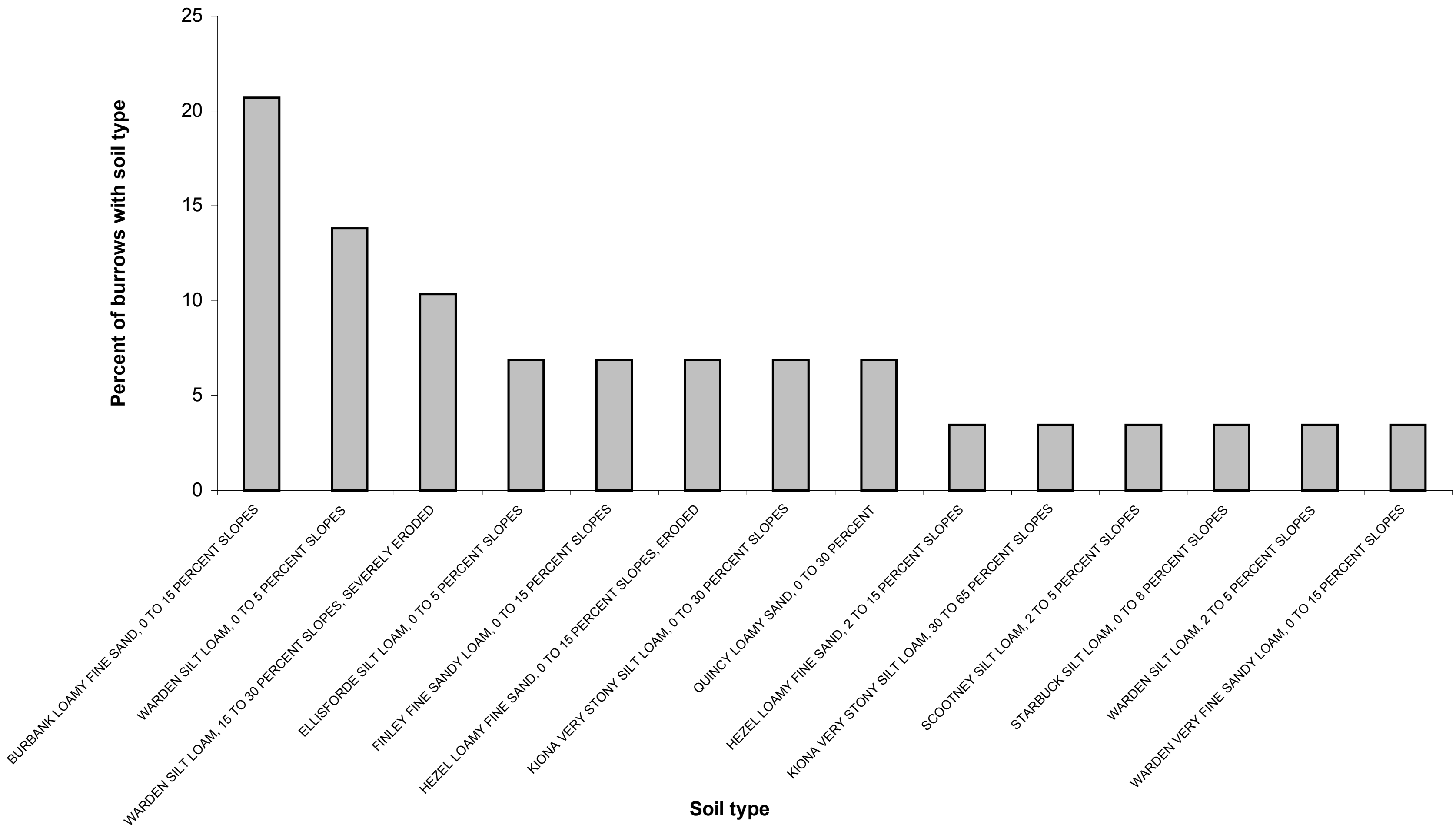

Table 15. Summary of winter survey re-sights with the number of birds present and the percent of birds from the previous breeding season present during the winter survey.

		Central WA		Southern WA	
		# present	% re-sighted	# present	% re-sighted
2001-2002	Owls detected	16		17	
	Banded	9		5	
	Adults	9	9%	5	9%
	Male	9	19%	4	17%
	Female	0	0%	1	3%
	Juveniles	0	0%	0	0%
	Unbanded	5		6	
	Band status unknown	2		6	
2002-2003	Owls detected	21		31	
	Banded	9		18	
	Adults	7	5%	15	12%
	Male	6	8%	13	21%
	Female	1	1%	2	3%
	Juveniles	2	1%	3	2%
	Unbanded	8		10	
	Band status unknown	4		3	
2003-2004	Owls detected	16		27	
	Banded	1		15	
	Adults	1	0.8%	13	10%
	Male	1	1.5%	12	17%
	Female	0	0%	1	1.7%
	Juveniles	0	0%	2	1%
	Unbanded	15		10	
	Band status unknown	0		2	

Appendix 1. Standardized Roadside Surveys Protocol

The goal of any survey or monitoring program is a standardized, repeatable protocol with high detection probability, low (temporal) variation in detection probability, and low observer variability; not necessarily to maximize numbers counted.

Systematic Survey Routes
The objective of the roadside surveys are: 1) to locate previously unknown nest locations in the study area, 2) to provide standardized survey information that can be replicated each year to allow estimation of population trend and 3) to detect any color-banded owls that were banded in previous years (or earlier in the current year) that may have moved to a new nest location.

We will identify systematic survey routes on topographic maps or road maps using all presumed passable roads (i.e., no 4-wheel drive or 2-tracks) within the core study area. Each route will follow a secondary road, and **all** roads within the core study area will receive routes. The location of particular survey points or route initiation points should in no way be influenced by the observer's previous knowledge of burrowing owl observations, historic records, or known nest sites. **Be sure to repeat all routes and all points from the previous year - use the GPS to locate exact survey points from last year and attempt to conduct the survey at each point at the same time of year as that point was surveyed the previous year.** Add additional routes each year to expand the core area and increase coverage of the study area.

Survey Points along a Survey Route
We survey all the roads within the core study area, but we will break up the areas into 4 km (2.5 mile) segments (survey routes). Each survey route will be approximately 4 km (2.5 miles) long and will include 10 survey stations each separated by approximately 400 m (0.25 miles). When choosing the exact location of a survey point you are allowed to move the point up to 200 additional meters along the road to allow a location with optimal viewing radius of the surrounding habitat. Adjacent survey points may be located more than 400 m (0.25 miles) apart if no burrowing owl habitat is available, but should not be located substantially less than 400 m (0.25 miles) apart. The location of each survey station must be accurately marked on a 7.5 minute topographic map or a gazetteer. Once downloaded to Map Source from GPS units the survey points' exact locations can also be seen by printing out maps from the program. A verbal description of its location (road and cross roads) and the UTMs recorded using the GPS receiver will also be recorded on the data sheet so that the exact survey location can be re-surveyed in future years.

At each survey station, the observer pulls off the road, parks on the road shoulder, exits the vehicle, and performs a 6-minute survey. The 6-minute survey consists of a 3-minute passive period (P1-P3) and a 3-minute call broadcast period (T1-T3 and S1-S3). During the 3-minute passive period the observer will scan the surrounding landscape. The 3-minute call-broadcast segment consists of 30 seconds of calls followed by 30 seconds of silence, with this pattern repeated 3 times. The first two 30-second call periods consist of the primary male song (coo-coooo) of burrowing owls, and the final 30-second call period consists of an alarm call (quick-quick-quick) (Haug et al. 1993).

Place the two speakers on top of the vehicle (highest point) with one speaker facing toward the left side of the road and the other speaker facing the right side of the road (i.e., perpendicular to the direction of traffic). Burrowing owl calls are broadcast at 80 dB (measured at 1m from the speaker) using a portable CD player and a mini-amplified speaker set.

Observers scan the landscape in a 360^{o} arc around the survey station during the entire 6-minute survey. The observer may move around a bit to ensure that the vehicle does not obstruct their view of the surrounding area. For each owl that is detected, observers record all survey segments during which each bird is heard and/or seen: 1st minute of passive period, 2nd minute of passive period, 3rd minute of passive period, 1st 30-second call period, 1st 30-second silent period, 2nd 30-second call period, etc.

Observers should use binoculars during the 6-minute survey **but not spotting scopes** since quality of spotting scopes vary and may not be available to future surveyors. Observers who have the use of spotting scopes should use their scope to verify possible owls/burrows **after the 6-minute survey is over** and record any additional information or detections observed using the spotting scope in the *Comments* column on the data sheet. Record any owls or burrows detected while driving between survey points in the *Before* column of the upcoming survey point. Observers also record the azimuth (degrees) and distance (m) to each owl detected, and whether the bird was at a burrow. Record whether each owl was detected visually, vocally, or both so that we can analyze all data together, as well as only visual or only vocal data so that we can avoid observer biases associated with vocal/visual surveys. Each adult owl detected at a survey point gets its own line, juveniles associated with one nest get one line for all juveniles. Hence, one nest detected at a point may produce 3 lines of data - one for the male, one for the female, and one for the juveniles. If no owls are detected at the survey point, there is one line filled out.

Once the 6-minute survey is complete, record the habitat types within a 200-m radius surrounding the survey point. Also record the percent of surrounding landscape (within the 200-m radius circle) that is visible from the survey point, and the percent of **the visible landscape** that is potential owl habitat.

Timing

Surveys will be conducted between mid-March and mid-July. Results from detection probability experiments during the first two years will be analyzed to identify the best time to conduct standardized surveys in future years. Surveys should be conducted between first light (typically ½ hour before sunrise) until 9:00am and between 6:00pm until dark. We will be evaluating the effects of time of day on detection probability and this survey window will be adjusted in future years based on initial results. Do not conduct surveys during excessive rain or when wind speed is >20 mi/hr.

Appendix 2. Central Washington Study Area Roadside Survey Point Locations

Point	UTM (NAD27 CONUS)	Point	UTM (NAD27 CONUS)	Point	UTM (NAD27 CONUS)
1	11 T 309026 5228864	54	11 T 318673 5219357	132	11 T 320010 5221058
2	11 T 321794 5226380	55	11 T 321888 5221430	133	11 T 319598 5221395
3	11 T 321784 5226017	57	11 T 321180 5221466	134	11 T 315581 5220905
4	11 T 321764 5225607	58	11 T 321578 5221439	135	11 T 315184 5220926
5	11 T 321449 5225535	59	11 T 320879 5222611	136	11 T 315829 5224141
6	11 T 321407 5225245	60	11 T 320888 5222999	137	11 T 315425 5224162
7	11 T 321502 5224885	61	11 T 320902 5223376	138	11 T 315047 5224184
8	11 T 321529 5224510	62	11 T 320922 5223858	139	11 T 314625 5224209
9	11 T 321570 5224247	63	11 T 320937 5224242	140	11 T 314435 5224531
10	11 T 321559 5223806	68	11 T 321210 5223910	141	11 T 314454 5224918
11	11 T 321556 5223450	69	11 T 320653 5223930	142	11 T 314473 5225392
12	11 T 321589 5223020	73	11 T 319218 5224010	143	11 T 314782 5220949
13	11 T 321649 5222596	74	11 T 318713 5224024	144	11 T 314393 5220964
14	11 T 321664 5222175	75	11 T 318247 5224037	174	11 T 313924 5220988
15	11 T 321820 5221737	76	11 T 317879 5224049	175	11 T 313433 5221002
16	11 T 321958 5221253	80	11 T 319477 5225616	176	11 T 313066 5221014
17	11 T 322159 5220787	81	11 T 318258 5219369	177	11 T 315706 5222525
18	11 T 322335 5220372	82	11 T 317671 5219387	178	11 T 315144 5222552
19	11 T 322616 5219980	83	11 T 317202 5219402	179	11 T 314626 5222576
20	11 T 322867 5219581	84	11 T 316764 5219416	180	11 T 314226 5222598
21	11 T 323082 5219223	85	11 T 316364 5219422	181	11 T 313832 5222614
22	11 T 322342 5219373	86	11 T 315948 5219435	182	11 T 313433 5222635
22	11 T 322693 5219186	87	11 T 315875 5219849	183	11 T 313027 5222653
23	11 T 322327 5219737	88	11 T 315897 5220275	184	11 T 312609 5222670
23	11 T 322355 5219314	89	11 T 315916 5220687	185	11 T 312219 5222699
24	11 T 321821 5219243	90	11 T 319122 5220741	186	11 T 311675 5222736
25	11 T 321382 5219245	97	11 T 319134 5219703	187	11 T 311158 5222997
26	11 T 321073 5219529	98	11 T 319153 5220145	188	11 T 311174 5223397
27	11 T 321180 5219928	99	11 T 319196 5221134	189	11 T 311192 5223798
28	11 T 321541 5220041	100	11 T 319214 5221583	190	11 T 311209 5224200
30	11 T 321863 5220327	101	11 T 319232 5222016	191	11 T 312699 5222051
32	11 T 321663 5220625	111	11 T 317629 5222778	192	11 T 312681 5221595
33	11 T 321187 5220651	112	11 T 317648 5223261	200	11 T 311897 5224364
34	11 T 320736 5220673	113	11 T 317668 5223699	201	11 T 312295 5224334
35	11 T 320172 5220698	114	11 T 319322 5224316	202	11 T 312697 5224303
36	11 T 319990 5220483	115	11 T 319332 5224644	203	11 T 313099 5224279
37	11 T 319968 5220095	116	11 T 319343 5225026	204	11 T 313497 5224256
38	11 T 319946 5219647	117	11 T 319357 5225401	205	11 T 313901 5224238
39	11 T 321050 5222277	118	11 T 319375 5225890	206	11 T 314401 5223875
40	11 T 320846 5221860	119	11 T 319387 5226302	207	11 T 314390 5223475
41	11 T 320821 5221336	120	11 T 319402 5226695	208	11 T 314371 5223075
42	11 T 319542 5220722	121	11 T 319412 5227047	214	11 T 312742 5223051
43	11 T 320631 5222295	122	11 T 319786 5227249	215	11 T 312756 5223454
44	11 T 320190 5222309	123	11 T 344151 5184084	216	11 T 312774 5223858
45	11 T 319590 5222345	124	11 T 343924 5184114	217	11 T 312816 5224686
46	11 T 319006 5222372	125	11 T 344151 5184106	218	11 T 312832 5225077
47	11 T 318479 5222393	126	11 T 319055 5225629	219	11 T 312850 5225483
48	11 T 318036 5222414	127	11 T 316060 5224535	220	11 T 329952 5218693
50	11 T 320808 5219274	128	11 T 317462 5224069	221	11 T 330350 5218676
51	11 T 320269 5219306	129	11 T 317075 5224085	222	11 T 330421 5219079
52	11 T 319711 5219324	130	11 T 316652 5224104	223	11 T 330438 5219481
53	11 T 319300 5219335	131	11 T 316235 5224124	224	11 T 330453 5219884

225	11 T 330465 5220286
226	11 T 330485 5220686
227	11 T 330497 5221088
228	11 T 330514 5221528
229	11 T 330528 5221963
230	11 T 330542 5222365
231	11 T 330558 5222782
232	11 T 330572 5223182
233	11 T 330589 5223586
234	11 T 330604 5223984
235	11 T 330617 5224402
236	11 T 330634 5224802
237	11 T 330653 5225203
238	11 T 330666 5225604
239	11 T 330680 5226004
240	11 T 330700 5226439
241	11 T 330545 5218328
242	11 T 330938 5218260
243	11 T 331336 5218192
244	11 T 331730 5218124
245	11 T 330067 5220329
246	11 T 329660 5220345
247	11 T 330868 5220296
248	11 T 331267 5220279
249	11 T 330937 5221918
250	11 T 331337 5221905
251	11 T 331747 5221888
252	11 T 332140 5221875
253	11 T 332542 5221862
254	11 T 332942 5221844
255	11 T 333344 5221829
256	11 T 333761 5221817
257	11 T 334161 5221799
258	11 T 334627 5221781
259	11 T 335031 5221763
260	11 T 335435 5221750
261	11 T 329015 5223621
262	11 T 329418 5223606
263	11 T 329829 5223589
264	11 T 330988 5223548
265	11 T 331387 5223533
266	11 T 331942 5223524
267	11 T 332341 5223500
268	11 T 332741 5223482
269	11 T 329060 5225471
270	11 T 330784 5225173
271	11 T 331184 5225155
272	11 T 331584 5225139
273	11 T 332051 5225117
274	11 T 332453 5225103
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276	11 T 333262 5225086
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281	11 T 335266 5225004
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286	11 T 333767 5222232
287	11 T 333785 5222633
288	11 T 333800 5223032
289	11 T 333813 5223440
290	11 T 333393 5223463
291	11 T 332202 5223875
292	11 T 332056 5224516
293	11 T 333828 5223839
294	11 T 333773 5224312
295	11 T 333859 5224642
296	11 T 333881 5225417
297	11 T 333893 5225820
298	11 T 328985 5224020
299	11 T 328998 5224426
300	11 T 329019 5224852
301	11 T 329059 5225874
302	11 T 329072 5226275
303	11 T 329086 5226670
304	11 T 329091 5227074
305	11 T 329115 5227468
306	11 T 329122 5227867
307	11 T 335836 5221731
308	11 T 336238 5221715
309	11 T 336639 5221701
310	11 T 337041 5221688
311	11 T 337442 5221669
312	11 T 337842 5221650
313	11 T 338243 5221636
314	11 T 338642 5221619
315	11 T 339044 5221598
316	11 T 333229 5217819
317	11 T 330708 5226846
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322	11 T 329140 5228264
323	11 T 329465 5228488
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327	11 T 331568 5228419
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329	11 T 332380 5228379
330	11 T 332645 5228367
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332	11 T 333443 5228327
333	11 T 333844 5228307
334	11 T 335229 5217741
335	11 T 335238 5218143
336	11 T 335252 5218544
337	11 T 335263 5218944
338	11 T 335280 5219394
339	11 T 335292 5219795
340	11 T 335306 5220192
341	11 T 335318 5220592
342	11 T 335334 5220990
343	11 T 335433 5222149
344	11 T 335385 5222546
345	11 T 335399 5222946
346	11 T 335410 5223346
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348	11 T 335445 5224147
349	11 T 335460 5224549
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351	11 T 335496 5225351
352	11 T 335512 5225754
353	11 T 335525 5226158
354	11 T 335529 5226564
355	11 T 335133 5226646
356	11 T 334730 5226662
357	11 T 334329 5226679
358	11 T 334835 5220151
359	11 T 334315 5220175
360	11 T 333907 5220188
361	11 T 333672 5219863
362	11 T 333661 5219443
363	11 T 333646 5219043
364	11 T 333626 5217823
365	11 T 334021 5217756
366	11 T 334417 5217694
367	11 T 334814 5217639
368	11 T 335236 5217669
369	11 T 335596 5217493
370	11 T 335996 5217426
371	11 T 336397 5217365
372	11 T 336790 5217302
373	11 T 337187 5217240
374	11 T 337583 5217175
375	11 T 337980 5217112
376	11 T 338379 5217138
377	11 T 332124 5218049
378	11 T 332522 5217984
379	11 T 332918 5217919
380	11 T 336820 5216810
381	11 T 336809 5216406
382	11 T 336794 5215997
383	11 T 336780 5215598
384	11 T 336761 5215197
385	11 T 338451 5216752
386	11 T 338437 5216350
387	11 T 338423 5215952
388	11 T 338409 5215552
389	11 T 336842 5217321
390	11 T 336854 5217771
391	11 T 336796 5218168
392	11 T 336530 5218472

393	11 T 336118 5218487	ML-441	11 T 335090 5213848	ML-497	11 T 338625 5222540
394	11 T 335715 5218498	ML-442	11 T 334731 5213657	ML-498	11 T 333920 5226649
395	11 T 335710 5220115	ML-443	11 T 334326 5213674	ML-499	11 T 333901 5226228
396	11 T 336114 5220097	ML-444	11 T 333807 5213689	ML-500	11 T 335827 5223359
397	11 T 336515 5220083	ML-445	11 T 333477 5214066	ML-501	11 T 336245 5223338
398	11 T 336989 5222092	ML-446	11 T 333496 5214627	ML-502	11 T 336663 5223317
399	11 T 337008 5222505	ML-447	11 T 333531 5215200	ML-503	11 T 337450 5223289
400	11 T 337022 5222913	ML-448	11 T 333530 5215605	ML-504	11 T 337853 5223277
401	11 T 337035 5223333	ML-449	11 T 339936 5213496	ML-505	11 T 338269 5223262
402	11 T 337050 5223736	ML-450	11 T 339503 5213513	ML-506	11 T 338634 5223045
403	11 T 337065 5224130	ML-451	11 T 339093 5213532	ML-507	11 T 334131 5218549
404	11 T 337080 5224530	ML-452	11 T 338612 5213555	ML-508	11 T 334651 5218536
405	11 T 337093 5224929	ML-453	11 T 338195 5213571	ML-509	11 T 334962 5218522
406	11 T 338585 5221221	ML-454	11 T 337773 5213578	ML-510	11 T 336748 5214752
407	11 T 338568 5220785	ML-455	11 T 337292 5213591	ML-511	11 T 336729 5214331
408	11 T 338557 5220385	ML-456	11 T 336720 5213600	ML-512	11 T 336716 5213962
409	11 T 338545 5219988	ML-457	11 T 336292 5213609	ML-513	11 T 335078 5213437
410	11 T 338535 5219619	ML-458	11 T 335846 5213620	ML-514	11 T 335056 5212988
411	11 T 338524 5219221	ML-459	11 T 335438 5213631	ML-515	11 T 335041 5212577
412	11 T 338512 5218821	ML-460	11 T 333543 5216013	ML-516	11 T 335019 5212156
413	11 T 338501 5218421	ML-461	11 T 333563 5216428	ML-517	11 T 335384 5212004
414	11 T 338486 5217979	ML-462	11 T 333575 5216835	ML-518	11 T 335824 5211994
415	11 T 338479 5217579	ML-463	11 T 333594 5217240	ML-519	11 T 336300 5212000
416	11 T 336937 5220065	ML-464	11 T 333605 5217647	ML-520	11 T 336796 5211983
417	11 T 337337 5220053	ML-465	11 T 333230 5217825	ML-521	11 T 337235 5211948
418	11 T 337738 5220040	ML-466	11 T 332709 5217905	ML-522	11 T 337871 5211929
419	11 T 338138 5220025	ML-467	11 T 332307 5217970	ML-523	11 T 338271 5211922
420	11 T 333968 5227861	ML-468	11 T 331965 5217510	ML-524	11 T 338283 5212473
421	11 T 333950 5227460	ML-469	11 T 331947 5216963	ML-525	11 T 338309 5212888
422	11 T 333936 5227061	ML-470	11 T 331932 5216560	ML-526	11 T 338687 5211913
423	11 T 331036 5226436	ML-471	11 T 332140 5216194	ML-527	11 T 339194 5211895
424	11 T 331406 5226587	ML-472	11 T 332561 5216177	ML-528	11 T 339664 5211882
425	11 T 331806 5226698	ML-473	11 T 333108 5216159	ML-529	11 T 339903 5212360
426	11 T 332195 5226767	ML-474	11 T 333931 5216130	ML-530	11 T 339940 5212829
427	11 T 338384 5214962	ML-475	11 T 335592 5216873	O-001	11 T 340756 5190927
428	11 T 338367 5214563	ML-476	11 T 336052 5216855	O-002	11 T 340351 5190961
429	11 T 338351 5214164	ML-477	11 T 336457 5216849	O-003	11 T 339941 5190988
430	11 T 338335 5213763	ML-478	11 T 337272 5216818	O-004	11 T 339387 5191015
431	11 T 338050 5214654	ML-479	11 T 337677 5216800	O-005	11 T 339090 5190737
432	11 T 344167 5184057	ML-480	11 T 338077 5216785	O-006	11 T 339075 5190316
029W	11 T 322302 5220271	ML-481	11 T 339988 5214131	O-007	11 T 339058 5189907
031W	11 T 322188 5220606	ML-482	11 T 339999 5214549	O-008	11 T 339141 5189430
056W	11 T 321889 5221429	ML-483	11 T 340017 5214996	O-009	11 T 339542 5189392
067W	11 T 321572 5223897	ML-484	11 T 340083 5215426	O-010	11 T 339949 5189366
110A	11 T 319253 5222493	ML-485	11 T 340086 5215879	O-011	11 T 340370 5189338
111A	11 T 319268 5222886	ML-486	11 T 339910 5216255	O-012	11 T 340699 5189616
112A	11 T 319284 5223267	ML-487	11 T 339636 5216746	O-013	11 T 340703 5190027
113A	11 T 319304 5223746	ML-488	11 T 334357 5216099	O-014	11 T 340732 5190470
ML-433	11 T 335206 5217237	ML-489	11 T 334765 5216087	O-015	11 T 341164 5190896
ML-434	11 T 335193 5216809	ML-490	11 T 335674 5216052	O-016	11 T 341567 5190875
ML-435	11 T 335183 5216389	ML-491	11 T 333627 5218610	O-017	11 T 341970 5190850
ML-436	11 T 335169 5215983	ML-492	11 T 333620 5218174	O-018	11 T 342386 5190814
ML-437	11 T 335152 5215567	ML-493	11 T 333699 5220348	O-019	11 T 342376 5190368
ML-438	11 T 335136 5215089	ML-494	11 T 333714 5220801	O-020	11 T 342352 5189927
ML-439	11 T 335122 5214667	ML-495	11 T 333738 5221301	O-021	11 T 342333 5189526
ML-440	11 T 335110 5214259	ML-496	11 T 338617 5222060	O-022	11 T 342036 5189249

O-023	11 T 341634 5189268	O-068	11 T 340534 5185446	O-113	11 T 339174 5181268
O-024	11 T 341229 5189292	O-069	11 T 340528 5185034	O-114	11 T 339601 5181240
O-025	11 T 340826 5189321	O-070	11 T 340518 5184626	O-115	11 T 340025 5181221
O-026	11 T 340662 5188951	O-071	11 T 340977 5184412	O-116	11 T 340457 5181140
O-027	11 T 340637 5188550	O-072	11 T 341474 5184391	O-117	11 T 340862 5181177
O-028	11 T 340622 5188149	O-073	11 T 341969 5184370	O-118	11 T 341264 5181142
O-029	11 T 340618 5187750	O-074	11 T 342169 5184716	O-119	11 T 341670 5181132
O-030	11 T 341024 5187723	O-075	11 T 342185 5185150	O-120	11 T 342075 5181115
O-031	11 T 341419 5187691	O-076	11 T 342199 5185594	O-121	11 T 342479 5181102
O-032	11 T 341835 5187672	O-077	11 T 342318 5185977	O-122	11 T 342885 5181088
O-033	11 T 342231 5187747	O-078	11 T 342745 5185955	O-123	11 T 343291 5181069
O-034	11 T 342260 5188151	O-079	11 T 343169 5185931	O-124	11 T 343695 5181075
O-035	11 T 342287 5188567	O-080	11 T 343576 5185911	O-125	11 T 343708 5181476
O-036	11 T 342310 5188967	O-081	11 T 343833 5186340	O-126	11 T 343719 5181875
O-037	11 T 342665 5189210	O-082	11 T 343846 5186755	O-127	11 T 343731 5182313
O-038	11 T 343123 5189181	O-083	11 T 343859 5187173	O-128	11 T 343746 5182872
O-039	11 T 343617 5189157	O-084	11 T 343865 5187594	O-129	11 T 343754 5183284
O-040	11 T 343961 5189413	O-085	11 T 343888 5187999	O-130	11 T 343317 5181881
O-041	11 T 343983 5189870	O-086	11 T 343932 5188715	O-131	11 T 342909 5181900
O-042	11 T 344000 5190284	O-087	11 T 343283 5187591	O-132	11 T 342490 5181914
O-043	11 T 343988 5190753	O-088	11 T 342805 5187616	O-133	11 T 342090 5181942
O-044	11 T 343408 5190784	O-089	11 T 343802 5185579	O-134	11 T 342108 5182343
O-045	11 T 342803 5190816	O-090	11 T 343793 5185028	O-135	11 T 342060 5182741
O-046	11 T 342214 5187324	O-091	11 T 343773 5184563	O-136	11 T 341626 5182763
O-047	11 T 342203 5186874	O-092	11 T 343765 5184163	O-137	11 T 341212 5182795
O-048	11 T 342208 5186313	O-093	11 T 343759 5183739	O-138	11 T 340953 5182469
O-049	11 T 341892 5186004	O-094	11 T 343439 5183493	O-139	11 T 341073 5182082
O-050	11 T 341347 5186024	O-095	11 T 343033 5183514	O-140	11 T 341187 5181695
O-051	11 T 340861 5186042	O-096	11 T 342620 5183534	O-141	11 T 341355 5181330
O-052	11 T 340567 5186557	O-097	11 T 342211 5183553	O-142	11 T 338714 5189441
O-053	11 T 340575 5187107	O-098	11 T 342156 5183982	O-143	11 T 338304 5189478
O-054	11 T 340017 5187790	O-099	11 T 340148 5184467	O-144	11 T 337901 5189491
O-055	11 T 339547 5187809	O-100	11 T 339718 5184500	O-145	11 T 337445 5189514
O-056	11 T 338983 5187858	O-101	11 T 339310 5184537	O-146	11 T 337025 5189517
O-057	11 T 338998 5188259	O-102	11 T 338873 5184570	O-147	11 T 336617 5189505
O-058	11 T 339013 5188662	O-103	11 T 338431 5184583	O-148	11 T 336213 5189524
O-059	11 T 339027 5189061	O-104	11 T 337830 5184604	O-149	11 T 344166 5184100
O-060	11 T 338956 5187424	O-105	11 T 337426 5184615	O-150	11 T 338474 5187844
O-061	11 T 338944 5187017	O-106	11 T 338835 5183976	O-151	11 T 338036 5187859
O-062	11 T 338930 5186617	O-107	11 T 338825 5183463	O-152	11 T 337502 5187875
O-063	11 T 338998 5186186	O-108	11 T 338809 5183059	O-153	11 T 344272 5187542
O-064	11 T 339398 5186148	O-109	11 T 338803 5182656	O-154	11 T 344803 5187512
O-065	11 T 339798 5186115	O-110	11 T 338790 5182249	O-155	11 T 345209 5187488
O-066	11 T 340200 5186077	O-111	11 T 338779 5181803	O-156	11 T 345717 5187462
O-067	11 T 340550 5185879	O-112	11 T 338758 5181357	O-157	11 T 346270 5187431

Appendix 3. Southern Washington Study Area Roadside Survey Point Locations

Point	UTM (NAD27 CONUS)				
1-1	11 T 338947 5123971	10-3	11 T 341093 5121910	16-3	11 T 335389 5125910
1-2	11 T 338837 5124328	10-4	11 T 340730 5121896	16-4	11 T 335404 5126343
1-3	11 T 338710 5124736	10-5	11 T 341020 5122150	16-5	11 T 341640 5121853
1-4	11 T 338597 5125103	10-6	11 T 341038 5122348	16-6	11 T 341932 5121832
1-5	11 T 338475 5125486	10-7	11 T 341037 5122351	16-7	11 T 342386 5121506
1-6	11 T 338350 5125837	10-8	11 T 340888 5122615	16-8	11 T 342760 5121038
1-7	11 T 338232 5126262	10-9	11 T 340888 5122615	16-9	11 T 342355 5121033
1-8	11 T 338113 5126605	11-1	11 T 339838 5122777	17-0	11 T 341996 5121045
1-9	11 T 337934 5126949	11-2	11 T 339733 5122482	17-1	11 T 341577 5121059
1-10	11 T 337737 5127305	11-3	11 T 339867 5123034	17-2	11 T 341149 5121078
2-1	11 T 337613 5127690	11-4	11 T 339523 5122924	17-3	11 T 340790 5121125
2-2	11 T 337529 5128065	11-5	11 T 339172 5122809	17-4	11 T 340399 5121609
2-3	11 T 337445 5128613	11-6	11 T 339068 5123134	17-5	11 T 340366 5121107
2-4	11 T 337386 5129003	11-7	11 T 339249 5123282	17-6	11 T 342391 5120600
2-5	11 T 337332 5129383	11-8	11 T 339024 5123605	17-7	11 T 342369 5120208
2-6	11 T 337271 5129791	11-9	11 T 339247 5122435	17-8	11 T 342353 5119776
2-7	11 T 337214 5130177	11-10	11 T 339372 5122029	17-9	11 T 342413 5119423
2-8	11 T 337150 5130591	12-0	11 T 339566 5123569	18-0	11 T 342034 5119656
2-9	11 T 337094 5130968	12-2	11 T 339706 5121771	18-1	11 T 342096 5119112
2-10	11 T 337035 5131361	12-3	11 T 339976 5120966	18-2	11 T 342019 5118763
3-1	11 T 337885 5127039	12-4	11 T 339751 5120547	18-3	11 T 342823 5119320
3-2	11 T 338166 5127329	12-5	11 T 339350 5120366	18-4	11 T 343192 5119210
3-3	11 T 338462 5127575	12-6	11 T 338722 5120610	18-5	11 T 343190 5119676
3-4	11 T 338735 5127649	12-7	11 T 338247 5120790	18-6	11 T 343416 5119945
4-1	11 T 338253 5127359	12-8	11 T 337553 5121097	18-7	11 T 343744 5120060
4-2	11 T 338465 5127119	13-0	11 T 340787 5121116	18-8	11 T 343624 5120410
4-3	11 T 338624 5126728	13-1	11 T 340802 5121559	18-9	11 T 343999 5120561
4-4	11 T 338715 5126386	13-2	11 T 340825 5121972	19-0	11 T 344424 5117622
4-5	11 T 338809 5126145	13-3	11 T 340841 5122464	19-1	11 T 344680 5117353
5-1	11 T 340012 5125111	13-4	11 T 340858 5122753	19-2	11 T 344955 5117053
5-2	11 T 339998 5124668	13-5	11 T 340260 5122745	19-3	11 T 345243 5116729
6-1	11 T 340091 5124595	13-6	11 T 340050 5122733	19-4	11 T 345406 5116422
6-2	11 T 339755 5124576	13-7	11 T 339920 5122191	19-5	11 T 345740 5116182
7-1	11 T 340099 5124332	13-8	11 T 339951 5121899	19-6	11 T 346165 5116002
7-2	11 T 339824 5124725	14-0	11 T 339499 5122161	19-7	11 T 346478 5115732
7-3	11 T 339763 5125058	14-1	11 T 339499 5122161	19-8	11 T 346742 5115433
8-1	11 T 337836 5126462	14-2	11 T 339432 5121921	19-9	11 T 347036 5115104
8-2	11 T 337575 5126828	14-3	11 T 339438 5121154	20-0	11 T 347280 5114747
8-3	11 T 338378 5123788	14-4	11 T 339108 5121166	20-1	11 T 347683 5114568
8-4	11 T 338482 5124112	14-5	11 T 338989 5122784	20-2	11 T 348062 5114539
8-5	11 T 337882 5125878	15-0	11 T 337225 5126904	20-3	11 T 348342 5114279
9-1	11 T 340072 5124034	15-1	11 T 336807 5126923	20-4	11 T 348631 5114043
9-2	11 T 340376 5123882	15-2	11 T 336243 5126931	20-5	11 T 349014 5114150
9-3	11 T 340686 5123628	15-3	11 T 337496 5124455	20-6	11 T 349220 5114408
9-4	11 T 340895 5123368	15-4	11 T 337054 5124448	20-7	11 T 348282 5114893
9-5	11 T 341231 5123009	15-5	11 T 336631 5124481	20-8	11 T 348512 5115248
9-6	11 T 341633 5122822	15-6	11 T 336245 5124354	20-9	11 T 348707 5115603
9-7	11 T 341678 5123531	15-7	11 T 335913 5124202	20-10	11 T 348725 5116255
9-8	11 T 342425 5122182	15-9	11 T 335318 5124291	20-11	11 T 348739 5116715
9-9	11 T 341792 5122515	16-0	11 T 335339 5124710	21-0	11 T 346371 5117660
10-1	11 T 341385 5122449	16-1	11 T 335357 5125093	21-1	11 T 346770 5117660
10-2	11 T 341180 5122283	16-2	11 T 335371 5125519	21-2	11 T 347187 5117647

21-3	11 T 347512 5117636	27-5	11 T 344928 5117793	34-2	11 T 342182 5109417
21-4	11 T 347913 5117617	27-6	11 T 344812 5118333	34-3	11 T 342209 5108854
21-5	11 T 348340 5117607	27-7	11 T 344785 5118971	34-4	11 T 342518 5108570
21-6	11 T 348740 5117600	28-0	11 T 338830 5119162	34-5	11 T 342941 5108184
21-7	11 T 349113 5117598	28-1	11 T 338967 5118731	34-6	11 T 343168 5107883
21-8	11 T 349568 5117602	28-2	11 T 339641 5118773	34-7	11 T 342967 5107537
21-9	11 T 350088 5117619	28-3	11 T 340010 5118532	34-8	11 T 342807 5107079
22-0	11 T 350433 5117512	28-4	11 T 339951 5118172	34-9	11 T 342721 5105565
22-1	11 T 350909 5117434	28-5	11 T 339239 5117940	35-0	11 T 336597 5115006
22-2	11 T 351327 5117189	28-6	11 T 339361 5117596	35-1	11 T 336180 5115191
23-1	11 T 346373 5118631	28-7	11 T 339793 5117149	35-2	11 T 335666 5115560
23-2	11 T 346372 5118089	28-8	11 T 339097 5117145	35-3	11 T 335298 5115849
23-3	11 T 348741 5119239	29-0	11 T 339046 5116497	35-4	11 T 334498 5115725
23-4	11 T 349086 5119232	29-1	11 T 338666 5116372	35-5	11 T 334003 5115750
23-5	11 T 349485 5119221	29-2	11 T 338626 5115931	35-6	11 T 333469 5114960
23-6	11 T 349895 5119219	29-3	11 T 338861 5115576	35-7	11 T 333936 5114923
23-7	11 T 350353 5119425	29-4	11 T 337468 5115327	35-8	11 T 333936 5114899
23-8	11 T 350913 5119587	29-5	11 T 337304 5114904	35-9	11 T 334294 5114745
23-9	11 T 351317 5119575	29-6	11 T 336972 5114800	37-0	11 T 334598 5114709
24-0	11 T 352462 5119535	29-7	11 T 337066 5115197	37-1	11 T 334901 5114477
24-2	11 T 353384 5119922	29-8	11 T 337131 5115568	37-2	11 T 331331 5116424
24-3	11 T 353657 5120235	30-0	11 T 336718 5118022	37-3	11 T 330898 5116609
24-4	11 T 353663 5120505	30-1	11 T 341547 5116958	37-4	11 T 330519 5116697
24-5	11 T 353292 5120576	30-2	11 T 341559 5117444	37-5	11 T 330153 5116654
24-6	11 T 353281 5120958	31-0	11 T 341395 5112864	37-6	11 T 329829 5116743
24-7	11 T 353070 5121157	31-1	11 T 341384 5112421	37-7	11 T 329421 5116966
24-8	11 T 353408 5121350	31-2	11 T 341510 5112181	37-8	11 T 329056 5117148
24-9	11 T 353664 5121541	31-3	11 T 341953 5112166	37-9	11 T 328676 5117374
24-10	11 T 354055 5121485	31-4	11 T 342218 5112162	37-10	11 T 328831 5117419
24-11	11 T 354118 5121006	31-5	11 T 342553 5111869	37-11	11 T 329044 5117396
25-0	11 T 354501 5121212	31-6	11 T 342843 5111687	38-1	11 T 330257 5115944
25-1	11 T 354721 5121458	31-7	11 T 342983 5111256	38-2	11 T 329842 5115931
25-2	11 T 354961 5121800	31-8	11 T 342938 5110812	38-3	11 T 329439 5115937
25-3	11 T 354919 5122173	31-9	11 T 342729 5110396	38-4	11 T 329363 5116256
25-4	11 T 354984 5122586	32-0	11 T 341082 5112209	38-5	11 T 329379 5116642
25-5	11 T 355259 5122424	32-1	11 T 340686 5112226	38-6	11 T 328322 5117520
25-6	11 T 355359 5122812	32-2	11 T 340262 5112243	38-7	11 T 327941 5117635
25-7	11 T 355749 5122858	32-3	11 T 339812 5112260	38-8	11 T 329744 5115084
25-8	11 T 356217 5123062	32-4	11 T 339575 5112113	38-9	11 T 329345 5115123
25-9	11 T 356600 5123087	32-5	11 T 339525 5111643	38-10	11 T 328968 5115132
26-0	11 T 347859 5118440	32-6	11 T 339166 5111787	40-0	11 T 327320 5117601
26-1	11 T 348278 5118488	32-7	11 T 341860 5112988	40-1	11 T 326861 5118555
26-2	11 T 348676 5118463	32-8	11 T 342488 5112962	40-2	11 T 326377 5118620
26-3	11 T 348997 5118287	32-9	11 T 342897 5112937	40-3	11 T 326008 5118608
26-4	11 T 346464 5120283	33-0	11 T 341574 5113832	40-4	11 T 325424 5118000
26-5	11 T 346483 5120768	33-1	11 T 342017 5113800	42-0	11 T 323581 5118280
26-6	11 T 346086 5120571	33-2	11 T 342376 5113783	42-1	11 T 322078 5118141
26-7	11 T 345710 5120436	33-3	11 T 342820 5113751	42-2	11 T 322055 5117749
26-8	11 T 345212 5119711	33-4	11 T 343265 5113735	42-3	11 T 321847 5117421
26-9	11 T 344809 5119235	33-5	11 T 343729 5113711	42-4	11 T 323162 5117982
27-0	11 T 347599 5120840	33-6	11 T 344228 5113698	42-5	11 T 322883 5117723
27-1	11 T 347281 5121300	33-7	11 T 344712 5113673	42-6	11 T 322678 5117419
27-2	11 T 347751 5121296	33-8	11 T 344957 5113358	42-7	11 T 322385 5117162
27-3	11 T 347567 5121107	34-0	11 T 342629 5110344	42-8	11 T 322075 5116930
27-4	11 T 345185 5118622	34-1	11 T 342400 5109897	42-9	11 T 321753 5116784

43-0	11 T 321422 5116721
43-1	11 T 321224 5116405
43-2	11 T 320801 5116252
43-3	11 T 320585 5115995
43-4	11 T 320989 5115791
43-5	11 T 321463 5115682
43-6	11 T 321972 5115665
43-7	11 T 322465 5115742
43-8	11 T 322943 5115815
43-9	11 T 323416 5115901
44-0	11 T 324000 5116241
44-1	11 T 324286 5116577
44-2	11 T 324525 5116964
44-3	11 T 324745 5117320
44-4	11 T 319509 5125301
44-5	11 T 318994 5125479
44-6	11 T 318531 5125646
44-7	11 T 318108 5125793
44-8	11 T 317716 5125927
44-9	11 T 317303 5126061
45-0	11 T 327561 5129633
45-1	11 T 327958 5129621
45-2	11 T 328355 5129610
45-3	11 T 328353 5130019
45-4	11 T 328166 5130381
45-5	11 T 328092 5130769
45-6	11 T 327914 5131123
45-7	11 T 327920 5131524
45-8	11 T 327922 5131921
45-9	11 T 327870 5132322
46-0	11 T 328951 5127374
46-1	11 T 328788 5127167
46-2	11 T 328610 5126827
46-3	11 T 328305 5126590
46-4	11 T 327940 5126382
46-5	11 T 327552 5126399
46-6	11 T 327175 5126415
46-7	11 T 326823 5126422
46-8	11 T 326344 5126545
46-9	11 T 325708 5127379
47-0	11 T 316762 5129990
47-1	11 T 316326 5130034
47-2	11 T 315832 5130049
47-3	11 T 315350 5130071
47-4	11 T 314937 5130087
47-5	11 T 314518 5130101
47-6	11 T 314003 5130232
47-7	11 T 313670 5130584
47-8	11 T 313459 5130943
47-9	11 T 313181 5131336
48-0	11 T 326559 5128085
48-1	11 T 326578 5128509
48-2	11 T 326423 5128763
48-3	11 T 326806 5129036
48-4	11 T 326621 5129314
48-5	11 T 326959 5128035
48-6	11 T 327363 5128129
48-7	11 T 327391 5128567
48-8	11 T 327419 5129030
48-9	11 T 327446 5129414
49-0	11 T 328752 5129600
49-1	11 T 329074 5129673
49-2	11 T 329095 5130132
49-3	11 T 329111 5130594
49-4	11 T 329129 5130996
49-5	11 T 328791 5131219
49-6	11 T 328341 5131231
49-7	11 T 327502 5131254
49-8	11 T 327104 5131188
49-9	11 T 327131 5130725
50-0	11 T 329496 5131188
50-1	11 T 329919 5131179
50-2	11 T 330157 5130829
50-3	11 T 330445 5130967
50-4	11 T 330397 5130493
50-5	11 T 330637 5130164
50-6	11 T 330919 5129789
50-7	11 T 330795 5129547
50-8	11 T 330363 5129561
50-9	11 T 330337 5127859
51-0	11 T 329654 5131547
51-1	11 T 329404 5131898
51-2	11 T 329116 5132300
51-3	11 T 328880 5132629
51-5	11 T 328071 5132859
51-6	11 T 327671 5132875
51-7	11 T 327271 5132886
51-8	11 T 327012 5132639
51-9	11 T 326695 5132232
52-0	11 T 316910 5126104
52-1	11 T 316459 5126114
52-2	11 T 315687 5126003
52-3	11 T 315277 5125937
52-4	11 T 314879 5125876
52-5	11 T 314479 5125811
52-6	11 T 314085 5125750
52-7	11 T 313693 5125690
52-8	11 T 313297 5125627
52-9	11 T 312902 5125571
54-4	11 T 328499 5132843

Appendix 4. Location of burrows used as nests (2000-2003) at the Central Washington Study Area.

Nest ID	UTM (NAD27 CONUS)			
BENCH2A	11	T	344051	5184428
BENCH3A	11	T	341119	5184385
BILL1C	11	T	342530	5188670
BIRD1	11	T	343590	5183488
BIRD2A	11	T	342954	5183734
BIRD2D	11	T	342956	5183618
BOOK2A	11	T	344024	5186350
BOOK5	11	T	343998	5187351
BOOK5B	11	T	343987	5187347
CEMRD2A	11	T	336810	5187091
CUN1	11	T	339845	5187803
DODN1	11	T	306261	5222025
DODN2	11	T	306380	5224922
DWAEA2	11	T	305560	5204572
DWAWA1	11	T	303958	5204413
DWAWA3A	11	T	304085	5204277
ELC1	11	T	335581	5221061
ELC3	11	T	336052	5220923
ELC6A	11	T	335872	5221248
ELC6B	11	T	335860	5221260
ELC7	11	T	335531	5221242
FIREHS2	11	T	332720	5228863
FIREHS2	11	T	332720	5228863
FOLEY1A	11	T	340181	5191759
FOLEY5	11	T	341488	5191078
FRONTO1	11	T	334916	5217799
FRONTQ2A	11	T	337453	5217529
FRONTQ3A	11	T	337524	5217657
FRONTQ4A	11	T	337153	5217539
FRONTQ5	11	T	337029	5217290
FRONTQ6A	11	T	337055	5217430
GEORGE1	11	T	285277	5220181
GEORGE2A	11	T	285439	5220245
GEORGE2A	11	T	285439	5220245
GEORGE3	11	T	285360	5220103
GEORGE3	11	T	285360	5220103
GEORGE4	11	T	284937	5220029
GEORGE5	11	T	285177	5220163
GILL1	11	T	339668	5186132
GLWA1	11	T	326733	5236923
GLWA11	11	T	326658	5237019
GLWA15	11	T	326629	5236963
GLWA16	11	T	326126	5236946
GLWA16A	11	T	326263	5236855
GLWA2	11	T	326634	5237049
GLWA4	11	T	326689	5236830
GLWA5A	11	T	326681	5236701
GLWA6	11	T	326233	5236933
GLWA7	11	T	326207	5236851
GLWA8	11	T	326326	5236895
GOLF1	11	T	321503	5223853
GOLF2	11	T	321390	5223809
H17-1A	11	T	333082	5214182
H17-2	11	T	337415	5188502
HATT1A	11	T	343341	5180649
HATTON2A	11	T	343134	5180655
HERM1A	11	T	337213	5194349
HERM2	11	T	336886	5194357
HWY17-3	11	T	337406	5192294
HWY17N1	11	T	318548	5232224
LEE1	11	T	337892	5189482
LEE2	11	T	337396	5189552
LEE2	11	T	337396	5189552
LEERD3	11	T	337815	5189270
LEERD4	11	T	341059	5189488
LEMA10	11	T	340919	5193741
LEMA10B	11	T	340925	5193741
LEMA3	11	T	340583	5187513
LEMA4A	11	T	340262	5185527
LEMA5A	11	T	340635	5188632
LEMA5E	11	T	340638	5188625
LEMA7	11	T	340643	5188730
LEMA8	11	T	340642	5188709
MAVA10C	11	T	319685	5221873
MAVA11	11	T	319689	5221929
MAVA11	11	T	319689	5221929
MAVA12	11	T	319542	5221945
MAVA2	11	T	319279	5221917
MAVA3	11	T	319512	5221855
MAVA4	11	T	319574	5221851
MAVA4	11	T	319574	5221851
MAVA5	11	T	319601	5221848
MAVA6	11	T	319626	5221850
MAVA8	11	T	319626	5221872
MAVA8	11	T	319626	5221872
MAVA8	11	T	319626	5221872
MAVA9B	11	T	319607	5221892
MIL1B	11	T	346289	5203108
MIL1B	11	T	346289	5203108
MLAIR1A	11	T	330333	5222869
MLHD1	11	T	317343	5223920
MLHD2	11	T	317369	5223922
MLHD3	11	T	317361	5223868
MLHD4	11	T	317419	5223812
MLHD4	11	T	317419	5223812
MOLA1	11	T	329643	5218393
MOLA2A	11	T	338901	5216844
MOLAG2A	11	T	326976	5228740
MOLAG3	11	T	327101	5228724
MOLAH2A	11	T	317695	5224609
MOLAH3	11	T	314395	5224167
MOLAH6	11	T	314412	5225746
MOLAHS1	11	T	328075	5219277
MOLAHS5	11	T	328077	5219173
MOLAHS6A	11	T	328326	5219136
MVRD1	11	T	313679	5220965
O14-2	11	T	335793	5190318
OTHAIR2	11	T	340975	5184462
OTHELLO1	11	T	344242	5176633
RD12NE1	11	T	328613	5236905
RD12NE2	11	T	328443	5237127
RD3SE2	11	T	343923	5211738
RD4NE1	11	T	318138	5224056
RD4NE1	11	T	318138	5224056
RD4NE2	11	T	317618	5224421
RD5NW1	11	T	309055	5226146
RD5NW2	11	T	309109	5226144
RD7NE1	11	T	331007	5228688
RD7NE3	11	T	331215	5228919
RD7NE4B	11	T	332072	5228390
RD7NE5B	11	T	332533	5228409
RD7NE5B	11	T	332533	5228409
RD7NE5B	11	T	332533	5228409
RD7NE6	11	T	331998	5228374
RD7NE6	11	T	331998	5228374
RD7NE7	11	T	332339	5228425
RD7NE7	11	T	332339	5228425
RD7NE8	11	T	332278	5228242

RD8NW1	11	T	292900	5231415
RD8SE1	11	T	345375	5203845
RD8SE1B	11	T	345320	5203891
RDANE1	11	T	312727	5226145
RDANE2	11	T	312722	5226117
RDANE2	11	T	312722	5226117
RDANE2	11	T	312722	5226117
RDANE2	11	T	312722	5226117
RDANE3	11	T	312617	5226236
RDANE4	11	T	312725	5226255
RDANE5	11	T	312715	5226166
RDANE9	11	T	312654	5226436
RDBNW1A	11	T	308080	5226162
RDBNW2	11	T	307947	5226118
RDBNW3	11	T	307208	5225443
RDBNW3	11	T	307208	5225443
RDDNW1A	11	T	304985	5229806
RDDNW3	11	T	305172	5230160
RDDNW3	11	T	305172	5230160
RDDNW4	11	T	305183	5229815
RDDNW4	11	T	305183	5229815
RDDNW6	11	T	305184	5229732
RDDNW7B	11	T	305323	5229797
RDDNW7B	11	T	305323	5229797
RDENW1	11	T	304057	5231241
RDENW1	11	T	304057	5231241
RDLNE1B	11	T	330360	5226441
RDLNE1B	11	T	330360	5226441
RDNNE1	11	T	333675	5220525
RDNSE2	11	T	333563	5216850
RDNSE2	11	T	333563	5216850
RDNSE4	11	T	333447	5216172
RDPNE1	11	T	337000	5221825
RDPNE1	11	T	337000	5221825
RDPNE2	11	T	337078	5224715
RDPNE2	11	T	337078	5224715
RDPNE3	11	T	336962	5221629
RDPNE3	11	T	336962	5221629
RDQF1	11	T	339143	5214749
RDQF1	11	T	339143	5214749
RDQF1	11	T	339143	5214749
RDQF3	11	T	338993	5214904
RDQNE1	11	T	338590	5221017
RDQNE2A	11	T	338617	5217658
RDQNE3	11	T	338368	5217713
RDQNE3	11	T	338368	5217713
RDQNE4	11	T	338204	5217843
RDQSE1A	11	T	338169	5214125
RDQSE1B	11	T	338224	5214217
RDQSE1C	11	T	338143	5214061
RDQSE2	11	T	338171	5214737
RDQSE3A	11	T	338048	5214655
RDQSE3B	11	T	338017	5214356
RDQSE3B	11	T	338017	5214356

RDRSE1A	11	T	339388	5215135
RDRSE1B	11	T	339393	5215128
RDRSE3	11	T	340140	5215592
RDRSE3	11	T	340140	5215592
RDUSE1	11	T	345193	5203947
RDUSE1C	11	T	345131	5203952
RDUSE2	11	T	345342	5204448
STEE3A	11	T	339068	5188120
STEE4A	11	T	338930	5186958
STEE5A	11	T	339273	5188990
STEE6	11	T	339211	5188421
STEE7	11	T	339387	5188659
SUTT1	11	T	336698	5193629
WARDEN11	11	T	344488	5202036
WARDEN1A	11	T	346092	5204203
WARDEN1D	11	T	345462	5204319
WARDEN2	11	T	346239	5203662
WARDEN3B	11	T	344541	5202112
WARDEN3B	11	T	344541	5202112
WARDEN3C	11	T	344440	5202159
WARDEN6	11	T	344632	5202036
WARDEN7	11	T	344576	5202027
WARDEN8	11	T	344736	5202144
WESTSHR1	11	T	321345	5226825
WHEEL1A	11	T	332221	5221661
WHEEL2	11	T	332210	5221753
WINRD1	11	T	303551	5234228
WSU1	11	T	344131	5183796
WSU2A	11	T	344094	5183558
WSU3	11	T	344364	5183705
WSU4	11	T	344355	5183585
WSU5	11	T	344944	5184210
WTRD1	11	T	293492	5228236
WTRD1	11	T	293492	5228236
WTRD2A	11	T	303279	5228285
WTRD3	11	T	303279	5228344
WTRD5	11	T	293665	5227946
WTRD6	11	T	293565	5228004

Appendix 5. Location of burrows used as nests (2000-2003) at the Southern Washington Study Area.

Nest ID	UTM (NAD27 CONUS)			
182-01	11	T	326820	5125300
240-01	11	T	319818	5134172
36-01	11	T	335321	5124212
397-01	11	T	339575	5120485
397-02	11	T	339187	5122702
54-01	11	T	318487	5129246
54-03	11	T	318436	5128884
54-05	11	T	318552	5129003
54-06	11	T	318466	5128486
54-07	11	T	318538	5128719
AINS01	11	T	338340	5120733
AINS02	11	T	338924	5120764
AINS03	11	T	339012	5120767
AIRP01	11	T	338406	5123897
AIRP02	11	T	338351	5123879
AIRP03	11	T	338237	5123897
AIRP05A	11	T	338473	5124347
AIRP06	11	T	337946	5125503
AIRP11	11	T	338284	5124369
AIRP14	11	T	338405	5124150
ALE03A	11	T	304912	5141174
ALE04A	11	T	303320	5138437
ALE09	11	T	304770	5141432
ALE10	11	T	302968	5150406
ALE11	11	T	309937	5138571
ALE12	11	T	309868	5138513
ARG64	11	T	332406	5124582
BADG02	11	T	322644	5119817
BADG03	11	T	322064	5119851
BADG04	11	T	322029	5119852
BADG05	11	T	321998	5119869
BADG06	11	T	321913	5119712
BADG07	11	T	321887	5119705
BUNO01	11	T	338304	5126599
CBC01	11	T	336808	5124386
CENEX01	11	T	339140	5124323
CENEX03	11	T	339155	5124046
CITY01	11	T	335516	5123901
COMM01	11	T	340989	5123256
COMM02	11	T	341134	5123107
COMM03	11	T	340700	5123488
CORI01	11	T	330945	5129640
CPGC02	11	T	325602	5125904
CPGC03	11	T	325708	5125950
CROSC04	11	T	334805	5124774
DALLAS01	11	T	319235	5121104
DENT01	11	T	326558	5128057
ESQU04	11	T	331136	5134413
ESQU05	11	T	331006	5134462
EXIT113-02	11	T	329952	5114346
EXT113-01	11	T	330010	5114306
FINK01	11	T	333819	5126965
FINK02	11	T	333991	5127087
FIREP02	11	T	336816	5124864
GILK01	11	T	311037	5131643
GILK03	11	T	311026	5131297
GLADE02A	11	T	337302	5128554
GLADE03	11	T	336963	5127218
GLADE04	11	T	336969	5127526
GLADE05	11	T	337331	5127093
H0RA07	11	T	321616	5132114
H0RA16	11	T	320876	5133196
HAMMER	11	T	320756	5136323
HORA00	11	T	321770	5132123
HORA01	11	T	320529	5133172
HORA03	11	T	320291	5133290
HORA06	11	T	320446	5133242
HORA16	11	T	320878	5133198
HORA19	11	T	320552	5133327
HUMP00	11	T	338379	5126048
HUMP01	11	T	338457	5126097
HUMP02A	11	T	338491	5126171
HUMP04	11	T	338220	5126740
HUMP05	11	T	338166	5126763
HUMP06	11	T	338369	5126471
HUMP07	11	T	338434	5126365
HUMP08	11	T	338343	5126567
HUMP09	11	T	338463	5126333
HUMP09A	11	T	338451	5126307
HUMP10	11	T	338447	5126246
HUMP11	11	T	338416	5125904
HUMP12	11	T	338328	5126753
HUMP13	11	T	338416	5126239
HUMP14	11	T	338362	5126356
IVYG08	11	T	331114	5122652
IVYG09	11	T	331262	5122609
IVYG11	11	T	331455	5122745
IVYG14	11	T	331125	5122761
IVYG18	11	T	331491	5122577
JAC04	11	T	318982	5120501
JAC05	11	T	318755	5120876
JAC06	11	T	318991	5120605
KALOT01	11	T	341399	5122807
KALOT02	11	T	341333	5122609
KARCH02	11	T	338600	5125627
KARCH03	11	T	338604	5125617
KARCH05	11	T	338748	5125493
KARCH07	11	T	338550	5125609
KING01	11	T	340042	5125250
LAMB01	11	T	322446	5131027
MMB05	11	T	339409	5120149
MYERS05	11	T	330977	5123249
NEWHS	11	T	335990	5124140
NONO1	11	T	333291	5124904
OREGN02	11	T	340142	5120862
OREGN06	11	T	340266	5120822
PARAD01	11	T	317646	5128590
PERK01	11	T	337882	5126806
PHIL07	11	T	353150	5120758
PHIL17	11	T	353117	5120793
RADIO01	11	T	337744	5127192
RAIN01	11	T	339097	5124645
RAIN02	11	T	339282	5124440
RD64-01	11	T	332328	5122535
RD64-01A	11	T	332341	5122572
REMO05	11	T	313135	5127162
RR06	11	T	338456	5125426
RR08	11	T	338485	5125330
RR10	11	T	338543	5125171
RR14	11	T	338946	5124139
RR16	11	T	338591	5124933
RR19	11	T	338348	5125907
RR21	11	T	338771	5124428
RR22A	11	T	337137	5129465
RR23	11	T	338569	5124988
SALT01	11	T	339678	5123068
SALT04	11	T	339763	5122949
SALT05	11	T	339599	5123248

SANDI02	11	T	330417	5127656
SANDI04	11	T	330373	5127274
SANDI05	11	T	330256	5127307
SANDI06	11	T	330312	5127330
SANDI07	11	T	329756	5127122
SANDI10	11	T	330026	5127513
SANDI12	11	T	330227	5127701
SANDI13	11	T	329604	5127760
SANDI14	11	T	329588	5127860
SANTA FE01	11	T	334919	5126976
SHELL01	11	T	331553	5126021
SUNW00	11	T	338099	5124136
SUNW01	11	T	337789	5123875
SUNW02	11	T	337969	5124047
SUNW03	11	T	338050	5124070
SUNW04	11	T	338109	5124040
SUNW05	11	T	338099	5123986
SUNW06	11	T	338096	5123952
SUNW07	11	T	338054	5123923
SUNW13	11	T	337648	5124230
SUNW20	11	T	337987	5124146
SUNW26	11	T	337835	5123704
SUNW34	11	T	337970	5124423
TAYLR02	11	T	331432	5133096
TERRIL06	11	T	339946	5111904
TWIN01A	11	T	338575	5126483
VAGI03	11	T	316397	5128976
VAGI05	11	T	316298	5128927
VAGI07	11	T	314119	5127183
VAGI08	11	T	314904	5127524
WALFART	11	T	332368	5116344
WILBUR01	11	T	338062	5127288
WSU03	11	T	325565	5133504
YOUNG03	11	T	328907	5120206